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Effect Of Boron And Zinc On The Growth, Yield And Yield Contributing Traits Of Tomato

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Abstract: *The present experiment was conducted to investigate the effect of boron and zinc on the growth and yield of tomato. Three levels of boron (viz., 0, 1 and 2kg H_3B0_3 ha^{-1}) and zinc (viz., 0, 1 and 2kg $ZnS0_4$ ha^{-1}) were applied for each experiment.Results revealed that boron had significant effect on all yield attributes and yield of tomato. Application of 2kg H_3B0_3/ha produced the highest tomato yield (79.2 ton ha^{-1}) through increasing plant height, number ofleaves per plant, number of branches per plant, number of flower clusters per plant, number fruits per plant, weight of fruits per plant, fruit weight, individual fruit length, fruit diameter and yield ha^{-1} of fruits. On the other hand, maximum yield of tomato was obtained from 2kg $ZnS0_4$ ha^{-1}. A combination of 2kg H_3B0_3 and 2kg $ZnS0_4$ ha^{-1} gave the highest yield of Tomato (83.50 ton ha^{-1}). So, application of 2kg H_3B0_3 along with 2kg $ZnS0_4$ ha^{-1} was the best for growth and yield of tomato.*

Keywords: *Tomato, Boron, Zinc, Growth, Yield*

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I. Introduction

Tomato (*Lycopersicon esculentum*), under the family Solanaceae is one of the most popular and important vegetable crops grown in Bangladesh. It ranks third in the world's vegetable production, next to potato and sweet potato, placing itself first as processing crop among the vegetables (Choudhury, 1979). It has a great demand throughout the year and generally grown in both winter and summer seasons. In Bangladesh, it is cultivated due to its adaptability to wide range of soil and climate (Ahmad, 1995). It is originated in tropical America (Salunkhe *et al*., 1987). However, in spite of its broad adaption, production is concentrated in a few area and rather dry area. Among the winter vegetable crops grown in Bangladesh, tomato ranks second in respect of production next to potatoes and third in respect of area (BBS, 2004). The recent statistics shows that in Bangladesh tomato was grown in 9,646.77 hectares of land and the total production was approximately 146,000 metric tons during the year 2009-2010 (BBS, 2010).

The popularity of tomato and its different products are increasing day by day. It is a nutritious and delicious vegetable used in salads, soups and processed into stable products like ketchup, sauce, marmalade, chutney and juice. They are extensively used in the canning industry for production of canned products. Tomato has high nutritive value especially vitamin A, B and vitamin C, carotenoids, lycopene, minerals e.g. calcium (Bose and Som, 1990; Rashid, 1983). Therefore, it can meet up some degree of vitamin A and C requirement, adds flavor to the foods, rich in medicinal value and also can contribute to solve malnutrition problem.

Boron plays an important role directly and indirectly in improving the yield and quality of tomato in addition to checking various diseases and physiological disorders (Magalhaes *et al.*, 1980). Boron affects the quality of tomato fruit, particularly size and shape, color, smoothness, firmness, keeping quality and chemical composition. Demoranville and Deubert(1987) reported that fruit shape, yield and shelf life of tomato were also affected by boron nutrition. The increase in vegetative growth of tomato could be attribute to physiological role of boron and its involvement in the metabolism of protein, synthesis of pectin, maintaining the correct water relation within the plant, resynthesis of adenosine triphosphate (ATP) and translocation of sugar at development of the flowering and fruiting stages (Bose and Tripathi, 1996).

In order to improve the quality of tomato, there should have the technologies, which will eventually fulfill the grower's as well as consumer's need. Studies on management practices, particularly on the management of boron would help increasing quality of tomato.Boron also has effect on many functions of the plant such as hormone movement, active salt absorption, flowering and fruiting process, pollen germination, carbohydrates, nitrogen metabolism and water relations in the plants. Boron deficiency causes reduced root growth, brittle leaves and necrosis of shoot apex. The improvement in quality parameters of tomato fruit due to boron application could be the result of overall growth and development of the crop (Naresh, 2002). Besides, application of Zinc increased significantly the dry biomass, fruit yield, fruit fresh weight and numbers of fruits per plants (Gurmani *et al.*, 2012).The basic Zn functions in plants are related to metabolism of carbohydrates, proteins, phosphates and also of auxins, RNA, and ribosome formations (Shkolnik, 1974).Keeping the above points in view, the present study was undertaken to evaluate the effect of boron and zinc on the growth and yield of tomato.

II. Materials And Methods

Location and characteristics of soil

The experimental plot was under the agro ecological zone of Old Himalayan Piedmont soil (AEZ-1). The area has irregular patterns of grey stratified, sands and silts. Those are moderately acidic throughout and parent alluvium is rich in minerals. Organic matter content is low and CEC is medium. Soil fertility level in general is low to medium. The selected experimental site was well drained medium high land. The soil was slightly acidic (pH 5.85). The percent organic carbon, nitrogen, total available boron and zinc were 1.29%, 0.07%, 0.39 and 3.0micro gram per gram ofsoil, respectively (Soil Testing Laboratory, SRDI, Dinajpur).

Climate

The experimental area belongs to subtropical climatic zone which is characterized by heavy rainfall, high humidity, high temperature and relatively long day period during “Kharif” season (April- September) and scarce rainfall, low humidity, low temperature and short day period during “Rabi” season (October-March). This climate is also characterized by distinct season’s viz., the monsoon or rainy season extending from May to October, the winter or dry season from November to February and pre-monsoon period or hot season from March to April (Edris*et al.*, 1979).

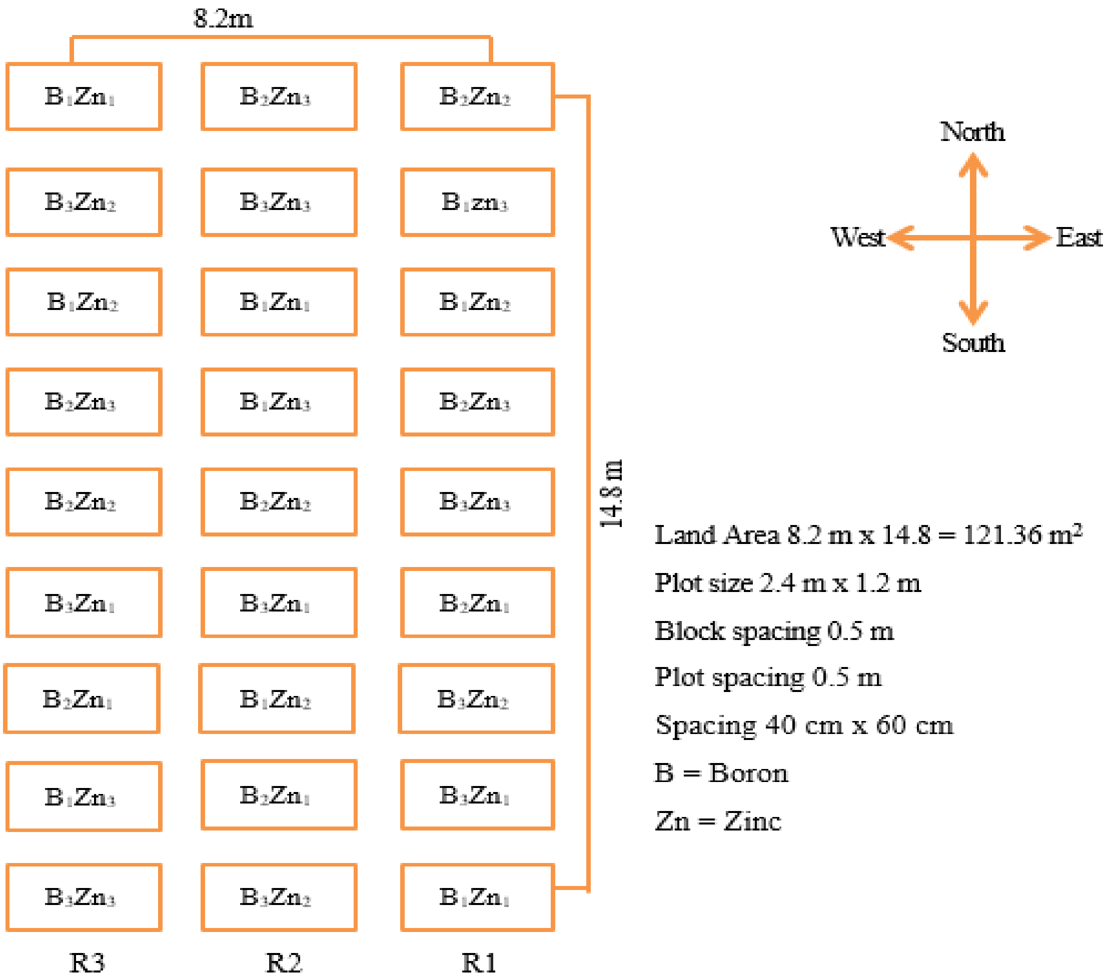

Figure 1: Layout of the experiment.

Plant materials

The tomato variety used in the experiment was "Maharaja F1".This is a high yielding variety. The seedlings were collected from BADC in Dinajpur.

Treatments of the experiment

There were 9 treatments combinations consisting of both B (0, 1 and 2kgha^{-1}) and Zn (0, 1 and 2 kgha^{-1}) and every treatment received nitrogen as urea (300 kg/ha), phosphorus astriple super phosphate, TSP (200 kg/ha) and potassium as Meurate of Potash, MP (210 kg/ha) as basal doses.

Design and layout of the experiment

The two factor experiment was laid out in the Randomized Complete Block Design (RCBD) with 3 replications. In total, there were 27 unit plots. The unit plot was 1.2m x 2.4m in size with a distance between unit plots was 50 cm. The layout of the experiment is shown in Figure 1.

Land preparation

At first the land was ploughed with a power-tiller on 12 November 2017 and kept open to sunlight. The after experimental plot was prepared by several ploughings and cross ploughings followed by laddering to break the clods and to level the soil. The weeds and stubble of previous crops were collected and removed from the plot. These operations were done to bring the land under good tilth for transplanting of tomato seedlings. The experimental plots were laid out in accordance with the experimental design.

Application of fertilizer

A basal dose of well-decomposed cow dung @ 10 t ha^{-1} was applied just after opening the land. TSP was applied at final land preparation. The urea and MoP were applied in two equal installments by band placement, first band after two weeks of transplanting and again after two weeks from the first band placement. The treatments of Zn as zinc sulphate and B as boric acid were properly distributed to 9 plots under 3 replications as per design of the experiment.

Transplanting of seedlings

Healthy and uniform sized 30 day old seedlings were transplanted in the experimental plots in the afternoon of 21 November, 2017 maintaining a spacing of 40 cm and 60 cm between the rows and plants. Light watering was applied immediately after transplanting by using water can.

Caring after seedlings

Gap filling was done in place of dead or wilted seedlings in the field using healthy seedlings of the same stock previously grown.Weeding was accomplished as and whenever necessary to keep the crop free from weeds, for better soil aeration and to break the soil crust.When the plants were well established, staking was given to each plant by *Bambusa* sticks to keep them erect. Within a few days of staking, the plants were pruned and there after only 2 or 3 main branches were kept before going to flowering stage**.**Irrigation was done whenever necessary. The young plants were irrigated by watering can. Beside this, irrigation was given four times at an interval of 12 days depending on soil moisture content. At the early stage of growth, some plants were attacked by insect pests (mainly leaf miner), and malathion 57 EC was sprayed at the rate of 2ml/liter at an interval of 15 days. Tomatoes were attacked by leaf blight, and Acrobat MZ was sprayed at the rate of 2ml/liter at an interval 15 days, and non-discovered plants were removed from the plots and destroyed.

Sampling of tomato fruits

Fruits were harvested at 3 days' interval during early ripe stage when they attained slightly red color. The harvesting was started from 15 February to 24 March, 2018.Tomato fruits were harvested in the morning. The collected fruits were carried in gunny bags and then half of the collected samples were immediately transferred to the store room. Proper care was taken while harvesting and handling to avoid any mechanical injury.Harvested tomato fruits were stored in safe place at Post Graduate Laboratory of the Department of Horticulture, Hajee Mohammad Danesh Science and Technology University, Dinajpur.

Data collection

Five plants were selected at random in such a way that the border effect could be avoided. For this reason, the outer two lines and the outer plants of the middle lines in each unit plot were avoided. Data were recorded periodically from the sample plants at 15 days' interval. The details of data recording are described below:

Plant height

The plant height was measured from the sample plants in cm. from the ground level to the longest stem and mean value was calculated. Plant height was recorded at15 days' interval starting from20days of planting up to 65 days to observe the growth rate of plants. Lastly, the plant height was recorded at final harvest.

Number of leaves per plant

Number of leaves per plant was counted from the sample plants and means value was calculated. Number of branches was recorded 20, 35, 50, 65 days after planting to observe the growth rate. Lastly, the plant leaves were recorded at final harvest.

Number of branches per plant

Number of branches per plant was counted from the sample plants and means value was calculated. Number of branches was recorded 35, 50 and 65 days after planting to observe the growth rate. Also counted number of branches per plant at final harvest day.

Number of flower clusters per plant

The number of flower clusters was counted from the sample plants periodically at 50 and 65 DAT, and the average number of flower clusters produced per plant was calculated.

Number of fruits per plant

$$\text{Number of fruits per plant} = \frac{\text{Total number of fruits in 5 sample plants}}{5}$$

Fruit length and Fruit breadth

The length of fruit was measured with a slide calipers from the neck of the fruit to the bottom of 5 selected marketable fruits from each plot and their average was taken in cm.The breadth of tomato fruit was also measured at the middle portion of 5 selected marketable fruits.

Weight of fruit per plant

The weight of fruits was measured with electric balance from the weight of five selected sample plants from each plot, and their average was calculated in gram.

$$\text{Wt. of fruits per plant} = \frac{\text{Total wt. of fruits in 5 sample plants}}{5}$$

Individual fruit weight

Among the total number of fruit during the period from first to final harvest, the fruits, expect the first and final harvest, was considered for determining the individual fruit weight by the following formula:

$$\text{Weight of individual fruit} = \frac{\text{Total weight of fruits}}{\text{Total number of fruit}}$$

Yieldper hectare

It was measured by the following formula:

$$\text{Fruit yield per hectare (ton)} = \frac{\text{Fruit yield per plot kg x10000m}}{\text{Area of plot in square meter (m2) x 1000 kg}}$$

Statistical analysis

The collected data were statistically analyzed to find out the level of significance using MSTAT-C package. The mean differences were compared by Duncan's Multiple Range Test (DMRT) at 5% level significance.

III. Results And Discussion

Main effect of boron on the growth and yield of Tomato

Plant height

From the result it was found that different levels of boron had significant effect on plant height of Tomato at 20, 35, 50, 65 and final harvest DAT (Table 1). At 20 DAT, the highest plant height (25.57 cm) was observed in B_3 (2 kg boron ha^{-1}) and control treatment (B_1) gave the shortest plant (14.0 cm). The longest plant (48.50 cm) was recorded from B_3 while the shortest plant (35.0 cm) was recorded from B_1 at 35 DAT. AT 50 DAT, the highest plant height (74.36 cm) was also observed in B_3 and the lowest plant height (60.28 cm) was observed in B_1. At 65 DAT, the longest (85.68cm) and the shortest (75.27cm) plant was recorded from B_1. Also at final harvest day the highest plant was recorded (100.98cm) at B_3 and shortest (82.40cm) was recorded from B_1.Respectively,similar results were reported by Sakamoto **(**2012).

Table 1: Main effect of different levels of boron on the plant height of tomato at different DAT and final harvest

Treatment	Plantheight (cm)				
	20DAT	35DAT	50DAT	65DAT	At final harvest
B_1	14.00c	35.00c	60.28c	75.27c	82.40c
B_2	22.37b	45.17b	72.26b	83.67b	93.38b
B_3	25.57a	45.17b	74.36a	85.68a	100.98a
LSD 0.05	3.073	5.953	3.858	1.332	1.011
Level of significance	**	**	**	**	**
CV (%)	4.65	3.78	3.33	0.97	0.65

DAT = days after transplanting, B_1 =0 kg, B_2 =1 kg/ha. B_3 = 2 kg/ha **= significant at 1% level

Number of leaves per plant

Number of leaves per plant of tomato varied significantly due to the application of different levels of boron at 20, 35, 50, 65 and at final harvest DAT (Table 2). At 20 DAT, highest (6.38) was recorded at Zn_3 (2 kg of Zn ha^{-1}) and the lowest (5.48) showed Zn_1 (zero treatment). At 35 DAT the maximum number of leaves per plant (13.34) was found in B_3 (2 kg boron ha^{-1}) while the minimum leaf number (8.30) was observed in B_1.At 50 DAT, the highest leaf numbers per plant (18.56) was obtained from B_3 and the lowest (11.32) from B_1.At 65 DAT, the highest leaf number per plant (20.98) was counted at B_1 and the lowest (14.03) from B_1.At final harvest DAT the maximum leaf number (27.90) at B_3 and minimum number of leaves (17.49)was recorded at B_1. Oyinlola (2004) reported that application of boron significantly increased the number of leaves on tomato plant compared to control.

Table 2: Main effect of different levels of boron on the number of leaves of tomato at different DAT and final harvest

Treatment	Number of leaves per plant				
	20DAT	35DAT	50DAT	65DAT	At final harvest
B_1	5.48b	8.30b	11.32c	14.03c	17.49c
B_2	6.31a	10.96ab	14.56b	17.89b	23.99b
B_3	6.38a	13.34a	18.56a	20.98a	27.90a
LSD 0.05	0.813	3.015	2.296	2.173	2.053
Level of significance	*	**	**	**	**
CV (%)	8.01	2.42	9.23	7.34	5.29

DAT = days after transplanting, B_1 =0 kg, B_2 =1 kg/ha. B_3 = 2 kg/ha, ** = significant at 1% level, *=significant at 5%.

Number of branches per plant

The variation in number of branches per plant at different levels of boron was also significant at 35, 50, 65 and final harvest DAT (Table 3). At 35 DAT, the maximum (2.611) was counted from Zn_3 (2 kg of Zn ha^{-1}) and the lowest (1.333) was found in Zn_1 (0 kg of Zn ha^{-1}). At 50 DAT, the highest number of branches per plant (6.36) was counted from B_3 whereas; the lowest number (3.51) was counted from B_1. At 65 DAT, the highest (11.0) and lowest (5.46) number of branches were also obtained from $B_1$and B_3, respectively. At final harvest, the maximum number of branches (17.17) was found in B_3 and the minimum also(7.52) was found in B_1, Respectively.Amrachandra and Verma (2003) also found similar findings in separate experiment.

Number of flower clusters per plant

Number of flower clusters per plant of tomato varied significantly due to the application of different levels of boron at 50 and 65 DAT (Table 3). AT 50 DAT, the maximum number of flower clusters per plant (10.6) was obtained from B_3 and the minimum (4.10) was from B_1. At 65 DAT, the highest number of flower clusters per plant (11.9) was recorded from B_3 and the lowest (9.50) was from B_1. Onofeghara (1983) also found similar result.

Table 3: Main effect of different levels of boron on the number of branches and number of flower cluster per plant of tomato

Treatment	Number of branches per plant				Number of flower cluster perplant	
	35DAT	50DAT	65DAT	At final harvest	50DAT	65DAT
B_1	1.33b	3.51c	5.46c	7.52c	4.10c	6.57c
B_2	2.34a	5.79b	8.50b	12.60b	6.53b	10.90b
B_3	2.61a	6.36a	11.03a	17.18a	10.60a	10.90a
LSD 0.05	0.450	0.130	0.130	1.582	1.536	0.813
Level of significance	*	**	**	**	**	**
CV (%)	12.82	1.43	0.92	2.19	2.5	1.6

DAT = days after transplanting, B_1 =0 kg, B_2 =1 kg/ha. B_3 = 2 kg/ha, ** = significant at 1% level, *=significant at 5%.

Number of fruits per plant

Significant variation was also recorded on number of fruits per plant of tomato due to the application of different levels of boron (Table 4). The highest yield (22.93) was recorded from B_3 (2 kg boron ha^{-1}) and lowest yield (13.58) was recorded from B_1 (0 kg boron ha^{-1}), respectively Ejaz *et al.* (2011) also reported that application of boron provides better results in number of fruits per plant of tomato as compared to control. This may be because boron takes part in active photosynthesis, which ultimately helps towards increase in number and weight of fruits per plant (Kumar and Sen, 2005).

Weight of fruits per plant

It was noticed that different levels of boron exhibited significant effect on the weight of fruits per plant (Table 4). The maximum weight (2587.7g) of fruits per plant was recorded in B_3 (2 kg boron ha^{-1}) and the minimum weight (1498.1 g) was obtained from control (0 kg boron ha^{-1}). Similar effects of different boron levels in respect of fruit weight per plant have been reported by Singh and Gangwar (1991).

Individual Fruit weight

Application of different levels of boron also showed significant differences for weight of individual fruit (Table 4). The highest individual fruit weight (98.6 g) was found from B_3 (2 kg boron ha^{-1}) while the lowest individual fruit weight (67.2g) was obtained from B_1 (no boron application). Oyinlola and Chude (2004) also found the similar results.

Fruit length

There was a significance of variation in fruit length due to different levels of boron (Table 4). The highest fruit length (6.17cm) was recorded from B_3 (2 kg boron ha$^{-1)}$ and the lowest fruit length (3.96cm) was recorded from B_1(0 kg boron ha^{-1}).

Fruit diameter

Diameter of tomato fruit also varied significantly due to the application of different doses of boron (Table 4). The highest diameter of fruit (9.53 cm) was recorded from B_3 (2 kg boron ha^{-1}) and the lowest diameter (4.53cm) was recorded from B_1 (0 kg boron ha^{-1}) (Table 4). Yadav *et al.* (2001) also found similar results.

Table 4: Main effect of different levels of boron on the yield contributing characters of tomato

Treatment	Number of fruits per plant	Weight of fruits per plant(gm)	Individual fruit weight(gm)	Fruit length (cm)	Fruit diameter (cm)
B_1	13.58c	1498c	67.2c	3.96c	4.53c
B_2	18.50b	2190b	85.1b	5.43b	7.06b
B_3	22.93a	3100a	98.6a	6.97a	9.53a
LSD 0.05	3.00	55.88	0.549	0.130	0.774
Level of significance	**	**	**	**	**
CV (%)	0.6	1.47	0.39	1.41	1.56
B_1 =0 kg, B_2 =1 kg/ha. B_3 = 2 kg/ha, ** = significant at 1% level.					

Yieldper hectare

Different levels of boron also significantly influenced on the yield of fruit per hectare (figure 2). The highest yield (79.2 t ha^{-1}) was produced due to the application of 2 kg boron ha^{-1} (B_3). On the other hand, the lowest yield (49.0 t ha^{-1}) was produced in control treatment (B_1). Ullah *et al.* (2015) also showed that application of boron gave higher yield per hectarethan untreated control in tomato.

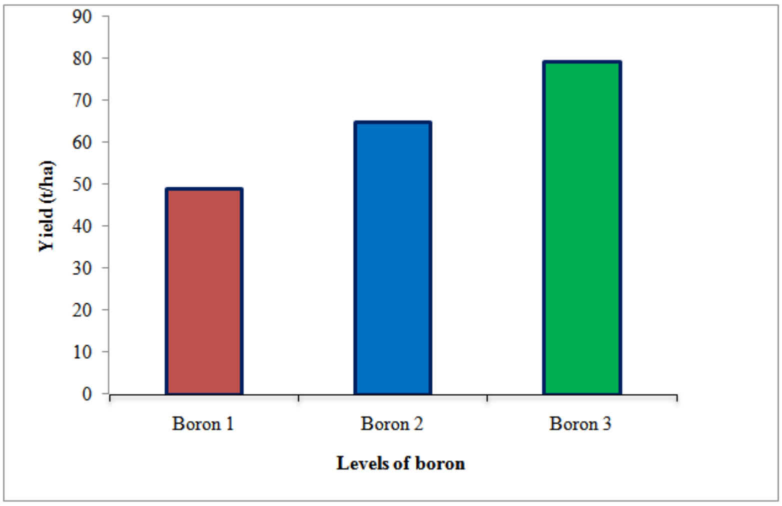

Figure 2: Effect of different levels of boron on yield of Tomato.

Main effect of zinc on the growth and yield of Tomato

Plant height

Plant height is one of the important parameter which is positively correlated with the yield of tomato. The levels of zinc fertilizer i.e. Zn_1 (0 kgha^{-1}), Zn_2 (1.0 kgha^{-l}) and Zn_3 (2 kgha^{-l})had significant and non-significant effect of Tomato plant height at stages 20, 35, 50, 65 and final harvest DAT (Table 5). At 20 and 35 did not show any significant variation in plant height. At 50 the tallest plant (72.94cm) was found in Zn_3 and the shortest (64.07cm) was found in Zn_1 (control). At 65 the highest (84.34cm) plant recorded Zn_3 and the shortest one (77.84cm) was recorded Zn_1. At final harvest the highest (100.9cm) recorded in Zn_3 and shortest (86.38) was recorded in $Zn_{1.}$Harris and Mathuma (2015) also found similar results.

Table 5: Main effect of different levels of zinc on the plant height of tomato at different DAT and final harvest

Treatment	Plant height (cm)				
	20DAT	35DAT	50DAT	65DAT	At final harvest
Zn_1	19.53a	40.93a	64.07b	77.84c	86.38c
Zn_2	20.67a	41.17a	69.88a	82.42b	91.83b
Zn_3	21.73a	42.17a	72.94a	84.34a	100.9a
LSD 0.05	10.57	12.23	5.435	1.335	1.507
Level of significance	NS	NS	**	**	**
CV (%)	4.65	3.78	3.33	0.97	0.65
DAT = days after transplanting, Zn_1 =0 kg, Zn_2 =1 kg/ha. Zn_3 = 2 kg/ha, ** = significant at 1% level, NS = non-significant.					

Number of leaves per plant

Number of leaves per plant of tomato varied significantly due to the application of different levels of Zinc at 20, 35, 50, 65 and at final harvest DAT (Table 6). At 20 DAT, did not show any significant variation in plant height. At 35 DAT the maximum number of leaves per plant (12.58) was found in Zn_3 (2 kg Zn ha^{-1}) while the minimum leaf number (9.8) was observed in B_1.At 50 DAT, the highest leaf numbers per plant (15.8) was obtained from Zn_3 and the lowest (14.4) from Zn_1.At 65 DAT, the highest leaf number per plant (19.8) was counted at Zn_1 and the lowest (16.4) from $Zn_{1.}$At final harvest DAT the maximum leaf number (24.4) at Zn_3 and minimum number of leaves (21.5) was recorded from $Zn_{1.}$ Similar results found by Singh and Tiwari, (2013).

Table 6: Main effect of different levels of zinc on the number of leaves of tomato at different DAT and final harvest

Treatment	Number of leaves per plant				
	20DAT	35DAT	50DAT	65DAT	At final harvest
Zn_1	5.67a	9.87b	13.37b	16.37b	21.51b
Zn_2	6.11a	10.14b	15.23ab	16.73b	23.48a
Zn_3	6.37a	12.58a	15.81a	19.88a	24.39 a
LSD 0.05	0.85	0.51	1.97	1.76	1.91
Level of significance	NS	**	**	**	**
CV (%)	8.01	2.42	9.23	7.34	5.29
DAT = days after transplanting, Zn_1 =0 kg, Zn_2 =1 kg/ha. Zn_3= 2 kg/ha, ** = significant at 1% level, NS = not significant					

Number of branches per plant

Number of branches per plant was also varied at different levels of zinc at 35, 50, 65 and 60 and final harvest of DAT (Table 7). At 35 DAT did not show any significant difference in number of branches per plant. AT 50 DAT the highest (5.85) number of branches was recorded B_3 (2 kg Zn ha^{-1}) and the lowest (4.55) was recorded B_1 (no treatment). At 65 DAT the highest (9.86) was recorded at Zn_3 and the lowest (7.02) was recorded $Zn_{1.}$ At final harvest day the highest (14.84) was recorded Zn_3 and the lowest (10.85) was recorded at Zn_1.

Number of flower clusters per plant

Significant variation was recorded on flower cluster per plant at 50 the highest number of flower clusters per plant (8.33) was recorded from Zn_3 (2 kg zinc ha^{-1}) and lowest (5.80) was recorded from Zn_1 (0 kg zinc ha^{-1}), but at 65 DAT did not show any variation at all (Table 7)

Table 7: Main effect of different levels ofzinc on the number of branches and number of flower cluster per plant of tomato

Treatment	Number of branches per plant				Number of flower clusters per plant	
	35DAT	50DAT	65DAT	At final harvest	50DAT	65DAT
Zn_1	2.04a	4.56	7.02c	10.86c	5.80a	9.95a
Zn_2	2.02a	5.24b	8.10b	11.60b	7.10a	10.60a
Zn_3	2.22a	5.86a	9.87a	14.84a	8.33a	11.20a
LSD 0.05	0.33	0.46	0.13	0.55	3.37	6.05
Level of significance	NS	**	**	**	**	NS
CV (%)	12.82	1.43	0.92	2.19	2.5	1.6

DAT = days after transplanting, Zn_1 =0 kg, Zn_2 =1 kg/ha. Zn_3= 2 kg/ha, ** = significant at 1% level, NS = non-significant.

Number of fruits per plant

Significant variation was recorded on number of fruits per plant of tomato due to the application of different levels of zinc (Table 8). The highest yield (20.53) was recorded from Zn_3 (2 kg zinc ha^{-1}) and lowest yield (16.21) was recorded from Zn_1 (0 kg zinc ha^{-1}),

Weight of fruits per plant

Three different levels of Zinc i.e. Zn_1 (0 kg Zinc ha^{-1}), Zn (1 kg Zinc ha^{-1}) and (2 kg Zinc ha^{-1}) significantly increased fruit weight per plant (Table 8). The highest (2587.66g) was recorded at Zn_1 (2 kg Zn ha^{-1}) and the lowest weight of fruit per plant (1999.11g) was recorded from Zn_1(0 kg Zn ha^{-1}).

Table 8: Main effect of different levels of zinc on the yield contributing characters of tomato

Treatment	Number of fruits per plant	Weight of fruits perplant(gm)	Individual fruit weight(gm)	Fruit length (cm)	Fruit diameter (cm)
Zn_1	16.21c	1999.11c	79.54c	4.69c	6.30a
Zn_2	18.26b	2201.67b	84.40b	5.50b	7.07a
Zn_3	20.53a	2587.67a	86.93a	6.17a	7.77a
LDS 0.05	10.88	55.88	0.54	0.13	5.22
Level of significance	**	**	**	**	NS
CV (%)	0.6	1.47	0.39	1.41	1.56

DAT = days after transplanting, Zn_1 =0 kg, Zn_2 =1 kg/ha. Zn_3= 2 kg/ha, ** = significant at 1% level, NS = not significant

Individual Fruit weight individual

Different levels of zinc Zn_1 (0 kg Zn ha^{-1}), Zn_2 (1 kg Zn ha^{-1}) and Zn_3 (2 kg Zn ha^{-1}) showed significance difference in fruit weight individual of tomato (Table 8). The highest (86.93g) was recorded Zn_3 and the lowest (79.54g) was recorded from $Zn_{1.}$

Fruit diameter

The effect different levels of zinc did not show significant variation on fruit diameter of tomato (Table 8).

Fruit length

There was a significant variation in fruit length due to different levels of zinc i.e. zinc Zn_1 (0 kg Zn ha^{-1}), Zn_2 (1 kg Zn ha^{-1}) and Zn_3 (2 kg Zn ha^{-1}). The highest fruit length (6.16cm) was recorded from Zn_3 and the shortest fruit length (4.68cm) was recorded from Zn_1 (Table 8).

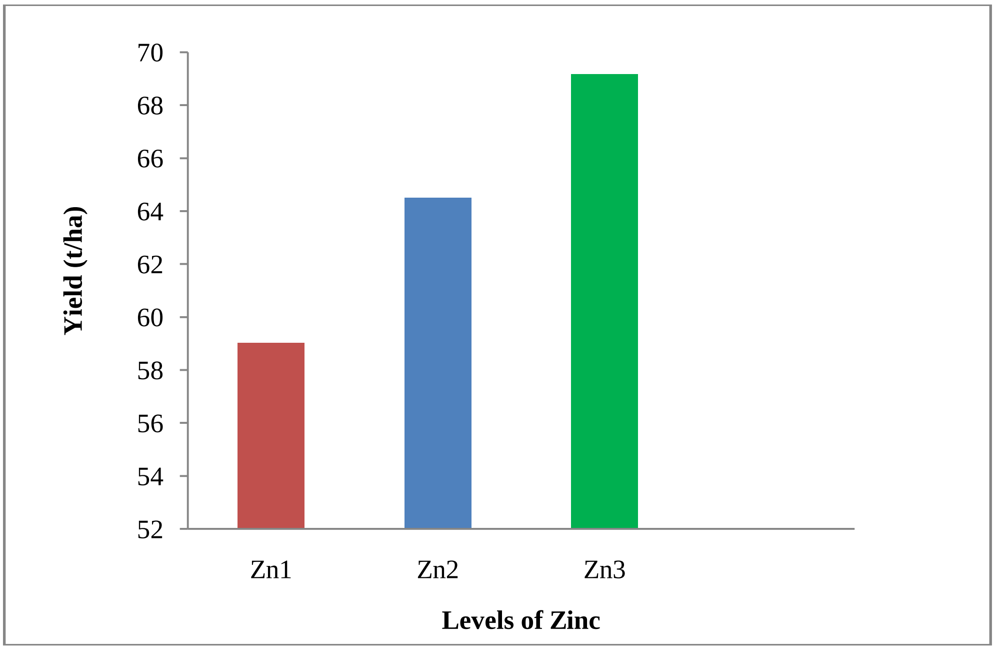

Figure 3: Effect of different levels of zinc on yield of tomato.

Yield per hectare

The results in (Figure 3) revealed that the different levels of zinc i.e. Zn_1 (0 kg of Zn ha^{-1}), Zn_2 (1 kg of Zn ha^{-1}) and Zn_3 (2 kg of Zinc ha^{-1}) showed a significant effect on fruit yield (t ha^{-1}). Zn_3 gave height yield (69.17) and the lowest yield was found from Zn_1 (59.02). Dube *et al.* (2003) reported that the application of zinc fertilizer significantly increased tomato yield over control.

Table 9: Combined effect of boron and zinc on the plant height of tomato at different DAT and final harvest

Treatment	Plant height (cm)				
	20 DAT	35 DAT	50 DAT	65 DAT	At final harvest
B_1Zn_1	13.00d	30.00d	54.73d	64.53e	74.80h
B_1Zn_2	20.10c	43.50ab	65.10c	82.96b	88.86f
B_1Zn_3	22.50bc	47.50cd	72.36b	86.03a	95.46d
B_2Zn_1	14.00d	35.50a	61.16c	79.63d	83.10g
B_2Zn_2	22.50bc	45.50ab	75.46ab	83.63b	90.43e
B_2Zn_3	25.50b	48.50a	73.00b	84.00b	101.96b
B_3Zn_1	15.00d	39.50bc	64.93c	81.63c	89.30f
B_3Zn_2	24.50b	46.50a	76.20ab	84.40b	100.83c
B_3Zn_3	28.70a	49.50a	77.70a	87.00a	105.53a
LSD 0.05	3.073	5.953	3.858	1.332	2.053
Significance Level	**	*	**	**	**
CV %	4.65	3.78	3.33	0.97	0.65

DAT = days after transplanting, B1 = 0 kg, B2 =1 kg/ha. B3= 2 kg/ha, Zn1 = 0 kg, Zn2 =1 kg/ha. Zn3= 2 kg/ha, ** = significant at 1% level, * = significant at 5% and NS = not significance.

Combined effect of boron and zinc on the growth and yield of tomato

Plant height

Due to combined effect of boron and zinc showed statistically significant variation on plant height at 20, 35, 50,65 and final harvest DAT (Table 9). At 20 DAT, the longest plant (28.70 cm) was obtained from B_3Zn_3 (2 kg boron with 2 kg zinc ha^{-1}) while the shortest plant (13.00 cm) was obtained from B_1Zn_1 (0 kg boron with 0 kg Zinc ha^{-1}). At 35 DAT, the highest plant height (49.50 cm) was observed in B_3Zn_3 and the lowest plant height (30.00 cm) was observed in B_1Zn_1. The longest plant (77.70cm) was recorded from B_3Zn_3, while the shortest plant (54.73cm) was recorded from B_1Zn_1 at 50 DAT. At 65 DAT, the longest plant (87.00cm) was recorded from B_3Zn_3 whereas the shortest plant (64.53cm) was recorded from B_1Zn_1. At final harvest day the highest (105.53cm) was recorded from B_3Zn_3 and the shortest (74.80cm) was recorded from B_1Zn_1.

Table 10: Combined effect of boron and zinc on the number of leaves per plant of tomato at different DAT and final harvest

Treatment	Number of leaves per plant				
	20 DAT	35 DAT	50 DAT	65 DAT	At final harvest
B_1Zn_1	4.63b	6.33e	9.30f	12.30f	14.60g
B_1Zn_2	6.70a	9.70cd	13.73de	17.06cd	23.46d
B_1Zn_3	6.70a	13.56ab	17.06bc	19.73b	26.46bc
B_2Zn_1	6.30a	8.20de	12.00e	14.46ef	17.43f
B_2Zn_2	6.10a	10.66bcd	14.96cd	18.00bc	24.53cd
B_2Zn_3	5.93a	11.60abc	18.80ab	17.73bc	28.46ab
B_3Zn_1	6.50a	10.36bcd	12.66de	15.33de	20.43e
B_3Zn_2	6.13a	12.50abc	14.96cd	18.60bc	23.96d
B_3Zn_3	6.50a	15.86a	19.80a	25.46a	28.76a
LSD 0.05	0.813	3.015	2.296	2.173	2.053
Significance Level	NS	**	**	**	**
CV %	8.01	2.42	9.23	7.34	5.29
DAT = days after transplanting, B1 = 0 kg, B2 =1 kg/ha. B3= 2 kg/ha, Zn1 = 0 kg, Zn2 =1 kg/ha. Zn3= 2 kg/ha, ** = significant at 1% level, * = significant at 5% and NS = not significance.					

Number of leaves per plant

Combined effect of boron and zinc illustrated statistically significant differences on number of leaves per plant at 20, 35, 50. 65 and final harvest DAT (Table 10). At 20 DAT, did not show significance variation in number of leaves per plant. At 35 DAT, the maximum number of leaves per plant (14.86) was found in B_3Zn_3 (2 kg boron with 2k Zinc ha^{-1}) while the minimum leaf number per plant (6.33) was observed in B_1Zn_1 (0 kg boron with 0 kg zinc ha^{-1}). At 50 DAT, the maximum number of leaves per plant (19.80) was found in B_3Zn_3 and the minimum number of leaves per plant (9.30) was found in B_1Zn_1. At 65 DAT, the highest leaf number per plant (25.46) was obtained from B_3Zn_3 whereas, the lowest leaf number (12.30) was obtained from B_1Zn_1. At final harvest DAT, the maximum (28.76) and minimum (14.60) leaf numbers per plant were observed in B_3Zn_3.

Number of branches per plant

There were statistically significant differences among the treatment combinations in respect of number of branches per plant at 35, 50, 65and final harvest DAT. The highest number of branches per plant (2.86) was obtained from B_3Zn_3 (2 kg boron with Zinc ha^{-1}) while the lowest number of branches per plant (1.26) was obtained from B_1Zn_1 (0 kg boron with 0 kg Zinc ha^{-1}) at 35 DAT. At 50 DAT, the highest number of branches per plant (6.80) was recorded from B_3Zn_3 whereas, the lowest number of branches per plant (2.56) was found in B_1Zn_1. At 65 DAT, the maximum number of branches per plant (13.60) was also counted in B_3Zn_3 and the minimum (4.36) was observed in $B_1Zn_{1.}$ At final harvest DAT, the maximum number of branches per plant (22.23) was also counted in B_3Zn_3 and the minimum (6.16) was observed in B_1Zn_1(Table 11).

Number of flower clusters per plant

Number of flower clusters per plant varied significantly due to the combined effect of boron and zinc at 50 and 65 DAT. At 50 DAT, the highest number (12.50) of flower clusters per plant was obtained from B_3Zn_3 whereas, the lowest number (3.10) was obtained from B_1Zn_1. At 65 DAT, the highest number (15.60) of flower clusters per plant was obtained from B_3Zn3and the lowest number (5.50) of flower clusters per plant was recorded from B_1Zn_1 (Table 11).

Table 11: Combined effect of boron and zinc on the number of branches, number of flower cluster of tomato

Treatments	Number of branches per plant				Number of flower cluster per plant	
	35DAT	50DAT	65DAT	Final DAT	50DAT	65DAT
B_1Zn_1	1.26c	2.56h	4.36i	6.16e	3.10g	5.50i
B_1Zn_2	2.33b	5.03e	7.50f	11.80c	5.50ef	9.50f
B_1Zn_3	2.53ab	6.06d	9.20d	14.60b	8.80c	13.50c
B_2Zn_1	1.26c	3.56g	5.50h	7.50de	4.30fg	6.60h
B_2Zn_2	2.36b	5.96d	8.50e	12.60c	6.50de	10.70e
B_2Zn_3	2.43ab	6.20c	10.30b	14.70b	10.50b	14.50b
B_3Zn_1	1.46c	4.40f	6.50g	8.90d	4.90ef	7.60g
B_3Zn_2	2.33b	6.30b	9.50c	13.40bc	7.60cb	12.50d
B_3Zn_3	2.88a	6.80a	13.60a	22.23a	12.50a	15.60a
LSD 0.05	0.45	0.13	O.13	1.58	1.53	0.81
Level of significance	**	**	**	**	**	**
CV (%)	12.82	1.43	0.92	2.19	2.5	1.6
DAT = days after transplanting, B_1 =0 kg, B_2 =1 kg/ha. B_3= 2 kg/ha, Zn_1 =0 kg, Zn_2 =1 kg/ha. Zn_3= 2 kg/ha, ** = significant at 1% level.						

Number of fruits per plant

Number of fruits per plant varied significantly due to the combined effect of different levels of boron and zinc, the highest number of fruits per plant (25.50) was obtained from B_3Zn_3 (2 kg boron with 2 kg zinc ha^{-1}) while the lowest number (10.64) was attained in B_1Zn_1 (0 kg boron with 0 kg zinc ha^{-1}) (Table 12).

Weight of fruits per plant

There was a significant combined effect of different levels of boron and zinc on the weight of fruits per plant. The maximum fruit weight per plant (3500g) was observed in the treatment combination of 2 kg boron and 2 kg zinc ha^{-1} and the lowest (1226 g) in this respect was found from the treatment combination 0 kg boron and 0 kg zinc ha^{-1} (Table 12).

Table 12: Combined effect of boron and zinc on the yield contributing traits of tomato

Treatments	Number of fruits per plant	Weight of fruits per plant (gm)	Individual fruit weight(gm)	Fruit length (cm)	Fruit diameter(cm)
B_1Zn_1	10.64e	1226i	63.63.h	3.36h	3.90g
B_1Zn_2	17.50cd	1971f	79.50e	4.50f	6.20e
B_1Zn_3	20.50bc	2800c	95.50b	6.20d	8.80b
B_2Zn_1	13.50e	1505h	67.50g	4.00g	4.80fg
B_2Zn_2	18.50cd	2100e	85.60d	5.30e	7.10d
B_2Zn_3	22.80ab	3000b	98.10a	7.20b	9.50b
B_3Zn_1	16.60d	1763g	70.50f	4.50f	5.10f
B_3Zn_2	19.50cd	2500d	90.20c	6.50c	7.90c
B_3Zn_3	25.50a	3500a	100a	7.50a	10.30a
LSD 0.05	3.007	55.88	0.54	0.13	0.77
Level of significance	**	**	**	**	**
CV (%)	0.6	1.47	0.39	1.41	1.56

DAT = days after transplanting, B_1 =0 kg, B_2 =1 kg/ha. B_3= 2 kg/ha, Zn_1 =0 kg, Zn_2 =1 kg/ha. Zn_3= 2 kg/ha, ** = significant at 1% level.

Individual Fruit weight

A significant variation on fruit weight (Table 12) was observed due to the combined of different levels of boron and zinc. With the increase of the levels, fruit weight also increased and it reached to 100gm at Treatment combination of 2 kg boron and 2 kg zinc ha^{-1} while Control treatment produced the lowest fruit weight individual (63.6g) of tomato per plant.

Fruit length

Significant variation was recorded due to the combined effect of different levels of boron and zinc for fruit length. The highest fruit length (7.50cm) was recorded from B_3Zn_3 (2 kg boron with 2 kg zinc ha^{-1}) whereas, the lowest individual fruit weight (3.36 cm) was observed from control treatment (0 kg boron with 0 kg zinc ha^{-1}) (Table 12).

Fruit diameter

Different levels of boron and zinc significantly influenced the diameter of fruit for their combined effect. The highest diameter of fruit (10.30cm) was obtained from the treatment combination of 2 kg boron and 2 kg zinc ha^{-1} while the lowest diameter of fruit (3.90cm) was obtained from B_1Zn_1 (0kg of boron with 0kg of zinc ha^{-1}) (Table 12).

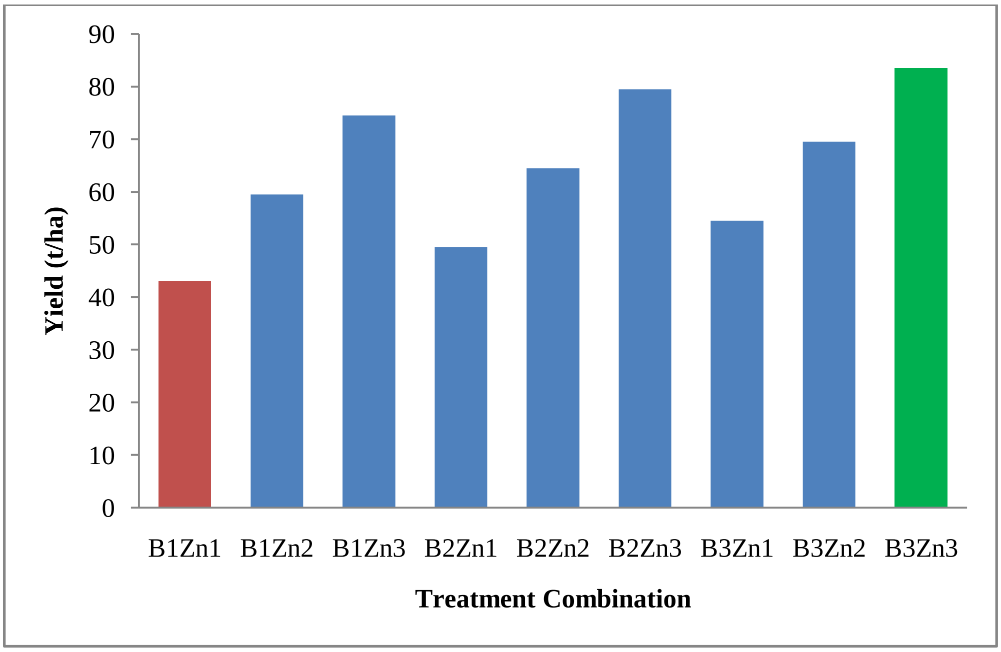

Figure 4: Effect of combined of boron and zinc on yield of Tomato.

Yield per hectare

Due to combined effect of different levels of boron and zinc performed significant effect on yield per hectare. The treatment combination of 2 kg boron and 2 kg zinc ha^{-1} gave the maximum yield (83.50 t ha^{-1}) and the minimum yield (43.06 t ha^{-1}) was found from the treatment combination of no boron and no zinc (Figure 4).

IV. Conclusion

A field experiment was conducted to find out the effects of Boron and Zinc on the yield and yield contributing traits of tomato.Results revealed that boron had significant effect on the plant height, number of leaves per plant, number of branches per plant, number of flower clusters per plant, number of fruits, weight of fruits per plant, individual fruit weight, fruit length, fruit diameter and yield per hectare. Application of 2 kg $H_3OB_3ha^{-1}$ gave the highest in all parameters compared to 1 kg H_3OB_3/ha.Also, some of the parameters studied were significantly influenced by different zinc levels while some parameters were not affected significantly by the different levels of zinc e.g.plant height at 20DAT, 35DAT, number of leaves at 20DAT,number of branches at 35DAT, number of flower cluster at 65DAT and fruit diameter. Interaction effect of boron (2 kg $H_3OB_3ha^{-1}$) and zinc (2 kg $ZnSO_4$/ha) exhibited significant variation on most of the characters studied, e.g. the plant height, number of leaves per plant, number of branches per plant, number of flower cluster per plant, number of fruits per plant, weight of fruits per plant, individual fruit weight, fruit length, fruit diameter and yield per hectare. But showed insignificant influence on number leaves per plant at 20DAT. So from the present study it may be concluded that $2kgha^{-1}$ boron combined with $2kgha^{-1}$ zinc was the best treatment combination. However, this study is conducted in a specific region, therefore, it is recommended to conduct research on the regional basis. In addition, response of the varieties to other fertilizer may be investigated in the future.

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