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Dissecting the response of magnesium and boron on growth and yield of different tomato varieties

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Key words: Magnesium, Boron, Tomato, Yield, Varieties

Abstract

A field experiment was carried out to study the role of Magnesium (Mg), Boron (B) and their combinations on three tomato varieties (Roma, Rio Grande and Yaqui) grown at Horticulture Research Farm, Department of Horticulture, The University of Agriculture Peshawar during 2017-18. The experiment was conducted using the Randomized Complete Block Design (RCBD) having a split plot pattern. Results indicated that Varieties, Magnesium, Boron and their interaction significantly influenced various growth and biochemical attributes of tomato. Concerning varieties, maximum plant height (77.95cm), number of branches plant^{-1} (10.35), number of flowers cluster^{-1} (8.61), number of flower clusters plant^{-1} (16.82) and yield (22.10 t ha^{-1}) was recorded for Rio Grande plants as compared to Roma and Yaqui. Regarding various magnesium and boron applications, highest plant height (87.79cm), number of branches plant^{-1} (10), number of flowers cluster^{-1} (8.99) and yield (21.43 t ha^{-1}) were noted with 5kg ha^{-1mg} + 2kg ha^{-1} B combined application. Furthermore, magnesium and boron applied at the rate of 5kg ha^{-1mg} + 1kg ha^{-1} B produced highest number of flower clusters plant^{-1} (17.09) in tomato plants. The interaction between VxT showed a significant increase in growth and yield attributes. The year wise comparison also resulted in significantly maximum growth and biochemical parameters during 2018 as compared to 2017. It is concluded that combined application of 5kg ha^{-1mg} + 2kg ha^{-1} B resulted in maximum growth and yield of tomato under agro climatic conditions of Peshawar.

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Introduction

Tomato (*Lycopersicom esculentum* Mill.) is the most popular vegetable initially introduced "Apple of Love" in Europe as early as in 1781 and attracts a great deal of attention due to increase in world population and demand. Tomatoes are generally low in calories and provides the recommended daily allotment (RDA) of various vitamins, proteins, iron, magnesium, potassium and sodium (USDA, 2016). The tomato is commonly eaten as fresh, can be baked, fried, pickled, or juiced as well as can be used in salads, sauces and soups (Saleem *et al.,* 2013).

Growing tomato under many constraints like climate, nutrition and diseases is a crucial task, while the fruit has to fulfill the market demand standards. Multiple other factors like poor soil, lack of awareness of modern technologies and equipment usage, poorly adopted and low yielding cultivars, limited number of approved varieties and limited irrigation resources adds to limited tomato yield in Pakistan (Gul, 2011). Physical appearance like size, shape, color, decay and defects as well as firmness and flavor are the key consumer preferences and can only be achieved if critical production factors are kept in consideration (Jones, 1999).

High fruit quality along with high yield is a top priority of any tomato grower and needs a proper irrigation, disease prevention, fertile soil, suitable climate, cultural practices and variety choice. Among various factors to be kept in mind, plant nutrition is the most important driving factor for getting a high yield of tomato (Fageria, 1992; Brady and Weil, 2002). Proper plant nutrition is essential for a bumper crop (Menzel and Simpson, 1987), enhance fruit quality parameters which ultimately results in profitability (Ganeshamurthy *et al.,* 2011).

Numerous research works has been conducted to investigate the influence of various plant nutrients on growth and production of tomato. For instance, Magnesium is involved in enzyme activation to trigger multiple energy transfer reactions and is a major constituent of chlorophyll molecule (Jones, 1999). Boron promotes quality attributes and yield of crops (Dale and Krystyna, 1998), enhance pollen germination and pollen tube elongation leading to high fruit set percentage (Abd-Allah, 2006) and is involved in stability of cell wall, RNA metabolism, respiration and cell membrane stability (Parr and Loughman, 1983). Boron also helps in tissues formation, root elongation as well as flower initiation and development (Perez-Lopez and Reyes-Jurado, 1983).

Magnesium and Boron are vital nutrients in tomato production and their deficiency occur because of low supply or antagonistic influence with other nutrients leading to a decline in growth and yield of tomato. Calcium and Magnesium strongly interfere with each other during the uptake process (Voogt, 1998) leading to the lower photoassimilate production and subsequent supply to various plant parts (Sonneveld and Voogt, 1991; Hao and Papadopoulos, 2003). Lower magnesium appears under various conditions like heat stress (Mengutay *et al.* 2013), acidic soils with low cation exchange capacity, leaching due to heavy rainfall (Gransee and Führs 2013; Sun *et al.* 2013), elements competing magnesium availability (Guo *et al.* 2016) and aluminum toxicity (Chen and Ma 2013). Boron deficiency is triggered by high pH of soil solution (Goldberg and Glaubig, 1986), high light intensity as well as low temperature (Dale and Krystyna, 1998). Plants deficient in boron encounter a decline in calcium level most specifically the Calcium metabolism in plant cell wall (Yamaguchi *et al.,* 1986).

Optimum availability of both Magnesium and boron in the nutrient solution could lead to an improved fruit quality and high yielding tomato crop. The aim of this research work was to determinemg: B ratios that can lead to high production and quality of tomato crop and their subsequent relationship to enhance heat stress tolerance in Peshawar agro-climatic condition.

Materials and methods

The experiment was carried out at Horticulture Research Farm, Department of Horticulture, The University of Agriculture Peshawar during 2017-18 with an objective to see "Effect ofmg and B on different tomato varieties under high temperature conditions". In this experiment two factors i.e. tomato varieties and different Magnesium and Boron levels were studied. There were a total of 27 treatments investigated in the experiment. The experiment was laid out in a Randomized Complete Block Design (RCBD) with split plot arrangement. Varieties (Roma, Rio Grande and Yaqui) were kept in the main plot while Magnesium (5kg ha^{-1} and 10kg ha^{-1}), Boron (5kg ha^{-1} and 10kg ha^{-1}) treatments were kept in sub plot. Magnesium sulphate was used as a source for magnesium and boric acid (H_3BO_3) for Boron application. Seeds of all the three tomato varieties i.e. Roma, Rio Grande and Yaqui were obtained from a local market and were sown in the month of January for raising nursery.

Soil bed preparation

The field was ploughed twice two weeks before the transplantation. Raised beds were prepared with a plant to plant distance of 60cm and row to row distance of 75cm. The experimental field soil was silty loam in texture having a 7.7 pH.

Fertilizer application

A recommended dose of NPK fertilizer in the form of Urea, Di ammonium phosphate (DAP), and Potassium Sulphate at the rate of 100, 90 and 60kg ha^{-1} respectively was applied to the field. Potassium and phosphorus were applied to the soil before seedlings transplantation while nitrogen fertilizer was given in two split doses. First dose was given before transplantation while the second dose was provided after 30 days of seedling transplantation. The soil was well irrigated immediately after transplantation while later the irrigation was carried out according to the plant requirement. Manual weeding/hoeing and earthing-up was performed regularly to avoid any weeds infestation.

Parameters studied

Data was collected on plant height (cm), number of branches $plant^{-1}$, number of flowers $cluster^{-1}$, number of flower clusters $plant^{-1}$, and yield (t ha^{-1}) using the standard protocols.

Results and discussion

Plant height (cm)

Data concerning plant height is shown in Table 1. Varieties were significantly different from one another regarding plant height of tomato.mg and B application either alone or in combination and years of plantation also significantly affected plant height of tomato while all the interactions were not significant. Regarding different varieties studied, Rio Grande resulted in tallest plants (77.95cm), followed by (74.45cm) in Roma, while smallest plants (71.31cm) resulted in Yaqui. Similarly, regarding various mg and B levels, the plant height increased from (58.17cm) in control to (87.79cm) with 5kg ha^{-1mg} + 2kg ha^{-1} B application, followed by (83.55cm) 5kg ha^{-1mg} + 1kg ha^{-1} B which was at par with that of (82.64cm) with 10kg ha^{-1mg} + 2kg ha^{-1} B application. Plant height was also significantly affected by mg and B application alone, with tallest tomato plants (69.23cm) in 5kg ha^{-1mg} and (77.25cm) observed in 2kg ha^{-1} B respectively as compared to control. Data regarding years of plantation revealed that plant height was maximum (75.64cm) during the year 2018 as compared to (73.50cm) during the year 2017.

Table 1. Effect of magnesium and boron on Plant height (cm) of tomato varieties.

Treatment	Years 2017	2018	Mean
Varieties			
Roma	73.84	75.07	74.45 b
Rio Grande	76.05	79.86	77.95 a
Yaqui	70.62	72.00	71.31 c
LSD (0.05)			1.30
Treatments (T)			
Control	56.59	59.75	58.17 g
5kg ha^{-1mg}	68.42	70.04	69.23 e
10kg ha^{-1}mg	67.88	69.22	68.55 e
1kg ha^{-1}B	63.29	65.79	64.54 f
2kg ha^{-1}B	76.25	78.25	77.25 d
5kg ha^{-1mg} + 1kg ha^{-1}B	81.99	85.10	83.55 b
5kg ha^{-1mg} + 2kg ha^{-1}B	87.26	88.32	87.79 a
10kg ha^{-1mg} + 1kg ha^{-1}B	78.60	80.28	79.44 c
10kg ha^{-1mg} + 2kg ha^{-1}B	81.23	84.04	82.64 b
LSD (0.05)			1.42
Mean	73.50 b	75.64 a	
Interactions			
Y x V	NS	Y x T	NS
V x T	NS	Y x V x T	NS

Means followed by similar letter(s) in column do not differ significantly from one another.

NS = Non-significant and *, ** = Significant at 5 and 1% level of probability, respectively.

Magnesium along with nitrogen, potassium and phosphorus fertilizers is emphasized for obtaining higher crop yield in recent decades (Cakmak and Yazici, 2010). Several research studies have confirmed the role of magnesium in plant structure, crop productivity as well as plant various functions (Senbayram *et al.*, 2015; Cakmak and Kirkby, 2008; Cakmak, 2013; Ceylan *et al.*, 2016). Increased plant height was due to sufficient magnesium supply which triggered the transportations of photosynthetic assimilates from leaves to sink organs especially shoot tips and roots (Hermans *et al.*, 2005; Lemoine *et al.*, 2013; Brohi *et al.*, 2000; Laing *et al.*, 2000). Optimized level of magnesium also helps in enhanced photosynthesis regulation (Nèjia *et al.*, 2016) along with increased enzymes activities like invertase and sugar synthase that are essential for sucrose transport from source to sink (White and Broadley, 2009). Our findings are in accordance with Singh *et al.* (2015) who obtained increased plant height in cotton plants applied with magnesium sulphate. Plant height increased with an increase in rate of calcium and magnesium application. Chapagain and Wiesman (2003) studied the influence of KCl-$MgCl_2$, KNO_3 and KCL fertigation on various morphological attributes of greenhouse tomato and observed that maximum plant height as well as chlorophyll content was recorded in plants treated with KCl+KCl.$MgCl_2$. Bryson and Barker (2002) experimented on peat medium grown tomato plants for optimizing fertilizer concentrations and noted an enhanced yield as well as various plant growth attributes when tomato plants were supplied with 4mm magnesium.

Boron role in plants is recognized as an essential element for growth and development since its discovery (Marschner, 1995). Increased plant height with increasing boron application can be related to the constructive role of boron in various plant processes and functions like metabolic pathways, sugar translocation, hormones regulation, roots growth and development, water transport to growing apical meristem and membrane functioning (Abdulnour *et al.*, 2000; Goldbach *et al.*, 2001; Liu *et al.*, 2000; Lou *et al.*, 2001). De Mello Prado *et al.* (2013) also reported a significant influence of boron application on plant height and plant dry matter of tomato plants. Similar results were obtained by Turhan (2020) who investigated the interactive influence of boron as well as mycorrhizal treatments on growth, quality and yield of tomato and reported an increase in shoot height fresh and dry matter content and leaf boron content. Similar results were also recorded by Zhao and Oosterhuis (2003) who noted a 27% increased plant height as compared to control with boron application. In another study, an increased plant height up to 10% was also recorded with foliar application of boron as compared to control (Dordas, 2006a).

Several research works have confirmed the role of boron nutrient in the cell division, elongation as well as structural integrity of cell wall and membranes (Marschner 1995; Cakmak and Romheld, 1997; Pollard *et al.*, 1977). Our findings are in conformity with Choi *et al.* (2015) who investigated boron partitioning in tomato plants and concluded that plant height, leaf length and width was significantly reduced 35-40% with no boron application as compared the plants treated with boron application. Increased plant height with boron treatment also might be due to interaction of boron with other nutrients. For instance, Yamauchi *et al.* (1986) observed an increased translocation of calcium to tomato leaves with adequate boron application. Davis *et al.* (2003) studied the role of foliar application of boron on growth, quality and yield attributes tomato and concluded that boron application considerably enhanced calcium, boron and potassium concentrations in plant tissues.

Number of branches plant^{-1}

Data for number of branches plant^{-1} is represented in Table 2. It is clear from the mean data that varieties,mg and B treatments and years of plantation significantly affected number of branches plant^{-1} of tomato. The interaction effect of YxV and YxVxT have also significant variation regarding number of branches plant^{-1}. Concerning number of branches plant^{-1} of tomato, Rio Grande plants produced maximum number of branches plant^{-1} (10.35), followed by (8.63) in Roma while least number of branches plant^{-1} (7.01) were produced in Yaqui. Number of branches plant^{-1} was also significantly affected by mg and B application, the highest number of branches plant^{-1} (7.92) and (8.18) resulted in 5kg ha^{-1} and 10kg ha^{-1}mg application respectively as compared to as compared to (7.02) in control. The number of branches plant^{-1} was 7.63 and 8.84 with application of B at the rate of 1kg ha^{-1} and 2kg ha^{-1} respectively, which was significantly higher than the control. Mean data also revealed that highest number of branches plant^{-1} (10) resulted in plants treated with 5kg ha^{-1}mg and 2kg ha^{-1} B which was at par with number of branches plant^{-1} (9.88) recorded with treatment of 5kg ha^{-1}mg and 1kg ha^{-1} B and were followed by (9.35) and (9.14) with 10kg ha^{-1}mg and 1kg ha^{-1} B and 10kg ha^{-1}mg and 2kg ha^{-1} B application respectively. Significant variations were also noted regarding year of planting and highest number of branches plant^{-1} (8.89) were produced in 2018 while 8.44 branches plant^{-1} were observed in the year 2017.

Table 2. Effect of magnesium and boron on number of branches plant^{-1} of tomato varieties.

Treatment	Years		Mean
	2017	2018	
Varieties			
Roma	8.29	8.98	8.63 b
Rio Grande	10.35	10.35	10.35 a
Yaqui	6.67	7.34	7.01 c
LSD $_{(0.05)}$			0.22
Treatments (T)			
Control	6.86	7.18	7.02 f
5kg ha^{-1}mg	7.79	8.05	7.92 de
10kg ha^{-1}mg	7.96	8.40	8.18 d
1kg ha^{-1} B	7.35	7.91	7.63 e
2kg ha^{-1} B	8.61	9.08	8.84 c
5kg ha^{-1}mg + 1kg ha^{-1} B	9.60	10.15	9.88 a
5kg ha^{-1}mg + 2kg ha^{-1} B	9.74	10.27	10 a
10kg ha^{-1}mg + 1kg ha^{-1} B	9.14	9.56	9.35 b
10kg ha^{-1}mg + 2kg ha^{-1} B	8.87	9.41	9.14 bc
LSD $_{(0.05)}$			0.30
Mean	8.44 b	8.89 a	
Interactions			
Y x V	*	Y x T	NS
V x T	NS	Y x V x T	***

Means followed by similar letter(s) in column do not differ significantly from one another.

NS = Non-significant and *, ** = Significant at 5 and 1% level of probability, respectively.

Interaction between Year and varieties revealed that Rio Grande plants produced highest number of branches plant^{-1} in the year 2018 as compared to other year and varieties interactions (Fig. 1). Interaction of varieties, mg and B treatments and years revealed that highest number of branches plant^{-1} were noted in Rio Grande plants treated with 5kg ha^{-1}mg and 2kg ha^{-1} B when planted in 2018 (Fig. 2).

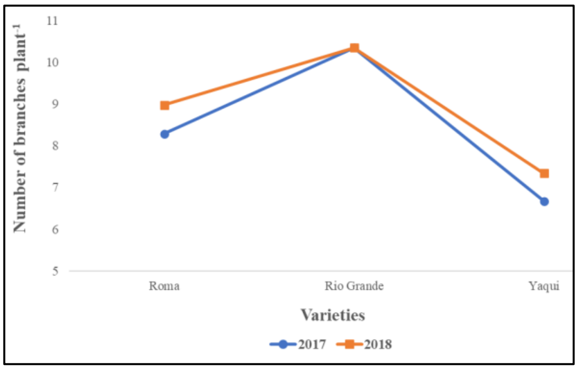

Fig. 1. Interactive effect of varieties, magnesium and boron treatment on number of branches plant^{-1} of tomato.

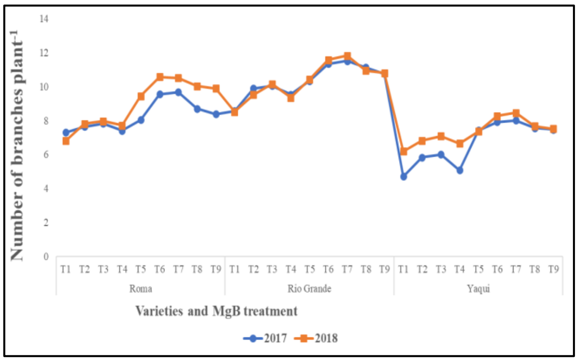

Fig. 2. Interactive effect of years, varieties, magnesium and boron treatment on number of branches plant^{-1} of tomato.

Number of branches were significantly increased by magnesium and boron application. These results support the study of Kasinath *et al.* (2015) who reported an increase in number of branches with optimum rate of magnesium application. The maximum number of branches with application of magnesium might be due to the perfect transfer of photosynthetic assimilates from leaves to various sinks resulting in normal growth and development (Cakmak *et al.*, 1994). Osman and El-Sawah (2009) investigated the response of two tomato cultivars

Saria and GLX to foliar application of magnesium in a two year study and observed an enhancement in various vegetative growth attributes including number of brancher plant-1, leaf area and number of leaves. Functionality of source organs to transport photo-assimilates to sink organs such as roots is highly disturbed with magnesium deficiency. Excess of magnesium application beyond optimum level have devastating effects on growth attributes, crop quality as well as overall yield (Gerendás and Führs 2013).

Boron application to tomato plants also significantly increased number of branches. Our results are supported by Sathya *et al.* (2010) who noticed an increased plant height as well as number of branches of tomato plants with boron treatment due to improved nutrient uptake and enhanced root development. Furthermore, Asad *et al.* (2003) reported enhanced calcium metabolism as a result of boron application which further increased number of branches per plant. Schon and Blevins (1990) also found a considerable increase in number of branches of soyabean with two split doses of foliar boron application. These results are also in conformity with Rab and Haq (2012) who reported increase in number of branches per plant and yield of tomato with foliar applied calcium chloride and borax. There are also reports of enhanced vegetative and reproductive attributes including number of branches, fruit weight, chlorophyll content and yield in several crops as a result of boron application (Haque *et al.*, 2000; Kazemi, 2013; Singh and Tiwari 2013).

Number of flowers cluster^{-1} and Number of flower clusters plant^{-1}

Data of number of flowers cluster^{-1} is represented in Table 3. It is clear from the mean table that varieties, mg and B treatments and years significantly affected number of flowers cluster^{-1} of tomato while all the interaction effects were not significant. Highest number of flowers cluster^{-1} (8.61) was observed in Rio Grande, followed by (7.38) in Roma, whereas least number of flowers cluster^{-1} (6.00) was recorded in Yaqui plants. Number of flowers cluster^{-1} was also significantly affected by mg and B application, whereas highest number of flowers cluster^{-1} (6.10) and (6.91) resulted in 5kg ha^{-1} and 10kg ha^{-1mg} application respectively as compared to as compared to (5.65) in control. The number of flowers cluster^{-1} was 6.34 and 7.84 with application of B at the rate of 1kg ha^{-1} and 2kg ha^{-1} respectively, which was significantly higher than the control. However, highest number of flowers cluster^{-1} (8.99) resulted in plants treated with 5kg ha^{-1mg} and 2kg ha^{-1} B, followed by (8.52) and (8.08) with 5kg ha^{-1mg} and 1kg ha^{-1} B and 10kg ha^{-1mg} and 2kg ha^{-1} B application respectively. Mean data also showed that highest number of flowers cluster^{-1} (7.56) were obtained in tomato plants grown in 2018 as compared to (7.10) in 2017.

Table 3. Effect of magnesium and boron on number of flowers cluster^{-1} of tomato varieties.

Treatment	Years		Mean
	2017	2018	
Varieties			
Roma	7.13	7.63	7.38 b
Rio Grande	8.41	8.82	8.61 a
Yaqui	5.77	6.23	6.00 c
LSD (0.05)			0.19
Treatments (T)			
Control	5.39	5.91	5.65 g
5kg ha^{-1mg}	5.96	6.25	6.1 fg
10kg ha^{-1}mg	6.62	7.20	6.91 e
1kg ha^{-1} B	6.09	6.59	6.34 f
2kg ha^{-1} B	7.63	8.05	7.84 cd
5kg ha^{-1mg} + 1kg ha^{-1} B	8.25	8.80	8.52 b
5kg ha^{-1mg} + 2kg ha^{-1} B	8.74	9.24	8.99 a
10kg ha^{-1mg} + 1kg ha^{-1} B	7.38	7.72	7.55 d
10kg ha^{-1mg} + 2kg ha^{-1} B	7.87	8.29	8.08 c
LSD (0.05)			0.26
Mean	7.10 b	7.56 a	
Interactions			
Y x V	NS	Y x T	NS
V x T	NS	Y x V x T	NS

Means followed by similar letter(s) in column do not differ significantly from one another.

NS = Non-significant and *, ** = Significant at 5 and 1% level of probability, respectively.

The mean data in Table 4 showed that number of flower clusters plant^{-1} was significantly affected by varieties, mg and B treatments and years of plantation. All the interactions except V x T were non-significant regarding number of flower clusters plant^{-1}. Highest number of flower clusters plant^{-1} (16.82) was observed in Rio Grande, followed by (14.87) in Roma, whereas least number of flower clusters plant^{-1} (12.54) was recorded in Yaqui plants. A significant variation was also observed in between mg and B treatments either alone or in combination. The number of flower clusters plant^{-1} increased from (11.74) in control plants to (13.98) with the application of 10kg ha^{-1mg}, followed by (12.59) with 5kg ha^{-1mg}. There was also an increase in number of flower clusters plant^{-1} from (13.25) to (15.03) with an increase of B application from 1kg ha^{-1} to 2kg ha^{-1} respectively.

Table 4. Effect of magnesium and boron on number of flower clusters plant^{-1} of tomato varieties.

Treatment	Years 2017	Years 2018	Mean
Varieties			
Roma	14.64	15.10	14.87 b
Rio Grande	16.70	16.94	16.82 a
Yaqui	12.45	12.63	12.54 c
LSD $_{(0.05)}$			0.20
Treatments (T)			
Control	11.49	11.99	11.74 h
5kg ha^{-1mg}	12.35	12.83	12.59 g
10kg ha^{-1}mg	13.90	14.05	13.98 e
1kg ha^{-1} B	13.11	13.39	13.25 f
2kg ha^{-1} B	14.93	15.13	15.03 d
5kg ha^{-1mg} + 1kg ha^{-1} B	16.99	17.19	17.09 a
5kg ha^{-1mg} + 2kg ha^{-1} B	16.87	17.09	16.98 a
10kg ha^{-1mg} + 1kg ha^{-1} B	15.60	15.93	15.76 c
10kg ha^{-1mg} + 2kg ha^{-1} B	16.13 b	16.42 a	16.27 b
LSD $_{(0.05)}$			0.30
Mean	14.60 b	14.89 a	
Interactions			
Y x V	NS	Y x T	NS
V x T	***	Y x V x T	NS

Means followed by similar letter(s) in column do not differ significantly from one another.

NS = Non-significant and *, ** = Significant at 5 and 1% level of probability, respectively.

The number of flower clusters plant^{-1} increased to (17.09) with 5kg ha^{-1mg} and 1kg ha^{-1} B treatment which was at par with (16.98) with 5kg ha^{-1mg} and 2kg ha^{-1} B application. The V x T interaction as represented in Fig 3, number of flower clusters plant^{-1} increased with increasing mg and B application rate for all tomato varieties as compared to control. However highest number of flower clusters plant^{-1} was recorded in Rio Grande when treated with 5kg ha^{-1mg} and 1kg ha^{-1} B. Data concerning number of flower clusters plant^{-1} revealed that highest number of flower clusters plant^{-1} (14.89) resulted in tomato plants grown in 2018 as compared to (14.60) in 2017.

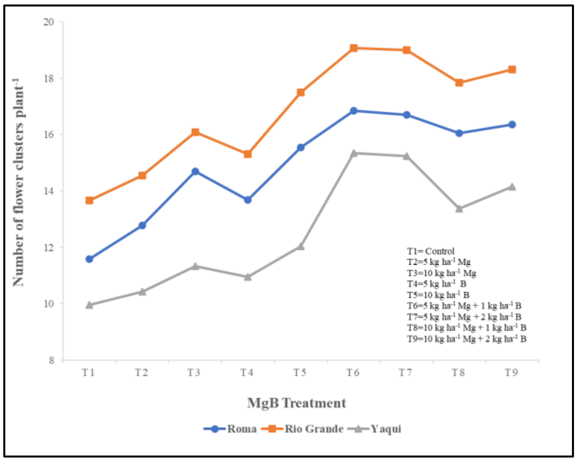

Fig. 3. Interactive effect of varieties, magnesium and boron treatment on number of flower clusters plant^{-1} of tomato.

An increase in magnesium concentration enhanced the number of flowers and flower clusters of tomato plants. Magnesium when is available to the plant in required concentration results in proper vegetative and reproductive growth of the plant. A balanced fertilizer application prevent magnesium deficiency when other cations like calcium ($Ca2+$) and potassium ($K+$) are present in excessive amount (Hermans *et al.*, 2013). A significant decline in reproductive growth, severe disease susceptibility and ultimately crop yield occurs due to antagonistic interactions of various cations with magnesium in soil (Brady *et al.*, 2005). Magnesium also play a fundamental role in biosynthesis and functioning of ATP (Igamberdiev and Kleczkowski, 2015). Our findings are also in conformity with Ceylan *et al.* (2016) who observed a decreased reproductive sinks development under magnesium deficiency and the impaired delivery of carbohydrates from the leaves was overcome by foliar application of magnesium fertilizer. El-Sayed *et al.* (2010) reported an increase in number of clusters plant^{-1}, number of flowers plant^{-1} in two tomato cultivars grown under high temperature stress conditions when treated with magnesium at the rate of 2000mg L^{-1}. Excessive magnesium supply has also been experimented on the metabolite content of tomato fruits as well as plants and a poor reproductive growth was recorded (Kwon *et al.*, 2019). Similar results were obtained by Pal and Mahajan (2017) who recorded higher flower yield with foliar application of magnesium as compared to water spray. The reason been restricted potential of plants to take magnesium nutrition from soil and limited availability in soil.

A direct influence of boron application on flower formation and development as well as pollen germination and fertilization has been confirmed in various crops in several research studies (Brown *et al.*, 2002; Dell *et al.*, 2002). Similar results were obtained by Rab and Haq (2012) who investigated the foliar application of calcium and boron in enhancing the growth as well as yield of tomato fruit. It was noted that maximum number of flowers per cluster, fruits per cluster and number of fruits per plant resulted in plants treated with f $CaCl_2$ (0.6%) + borax (0.2%). It was also confirmed from a research work that decreasing boron level directly influence number of flowers and fruits in tomato (Dell and Huang, 1997). Similar results were also reported in various other crops including rice (Sharma *et al.*, 1981), soybean (Mascarenhas *et al.*, 1990) as well as rapeseed (Myers *et al.*, 1983). A decline in flower and fruit number was noted with low boron level as compared to optimum application. The reason been less translocation of assimilates to sink organs from the source (leaves) under boron deficiency. Also insufficient boron availability around root zone lead to flower abscission due to limited translocation of boron to the plant leaves and reproductive tissues (Smit and Combrink, 2004).

Yield (t ha^{-1})

It is clear from Table 5 for yield that there was a significant difference among varieties and mg B treatments while the year of planting showed a non-significant influence on the yield of tomato. Maximum yield (22.10 t ha^{-1}) was obtained in Rio Grande, followed by (19.58 t ha^{-1}) in Roma, whereas reduced yield (16.91 t ha^{-1}) was noted in Yaqui plants. There was a significant variation between mg and B treatments either alone or in combination regarding yield. The yield increased from (17.13 t ha^{-1}) in control plants to (18.95 t ha^{-1}) with the application of 10kg ha^{-1mg}, followed by (18.08 t ha^{-1}) with 5kg ha^{-1mg}. An increase in yield was also recorded from (19.15 t ha^{-1}) to (19.43 t ha^{-1}) with an increase of B application from 1kg ha^{-1} to 2kg ha^{-1} respectively but was significantly not different. The yield increased to (21.43 t ha^{-1}) with 5kg ha^{-1mg} and 2kg ha^{-1} B treatment, followed by (20.97 t ha^{-1}) with 5kg ha^{-1mg} and 1kg ha^{-1} B application.

Table 5. Effect of magnesium and boron on Yield (t ha^{-1}) of tomato varieties.

Treatment	Years		Mean
	2017	2018	
Varieties			
Roma	19.52	19.64	19.58 b
Rio Grande	22.05	22.14	22.10 a
Yaqui	16.87	16.95	16.91 c
LSD (0.05)			0.19
Treatments (T)			
Control	17.06	17.21	17.13 g
5kg ha^{-1mg}	18.04	18.13	18.08 f
10kg ha^{-1}mg	18.89	19.00	18.95 e
1kg ha^{-1} B	19.09	19.22	19.15 de
2kg ha^{-1} B	19.40	19.46	19.43 d
5kg ha^{-1mg} + 1kg ha^{-1} B	20.89	21.06	20.97 b
5kg ha^{-1mg} + 2kg ha^{-1} B	21.38	21.49	21.43 a
10kg ha^{-1mg} + 1kg ha^{-1} B	20.28	20.32	20.3 c
10kg ha^{-1mg} + 2kg ha^{-1} B	20.30	20.33	20.32 c
LSD (0.05)			0.32
Mean	19.48	19.58	
Interactions			
Y x V	NS	Y x T	NS
V x T	NS	Y x V x T	NS

Means followed by similar letter(s) in column do not differ significantly from one another.

NS = Non-significant and *, ** = Significant at 5 and 1% level of probability, respectively.

Optimum dose of magnesium can lead to increased yield as well as fruit quality. Our results are supported by Bryson and Barker (2002) who carried out experimental study to optimize fertilizer concentrations for tomato and recorded an increase in plant growth attributes and yield with magnesium application at the rate of 4mm mg^{2+} in peat-based medium. Hao and Papadopoulos (2003) proposed a 4.16-6.7mm of mg^{2+} treatment for tomatoes grown in rockwool which resulted in highest yield and fruit quality. Magnesium deficiency in plants considered to be more sensitive to drought stress and its optimum dose can prevent from yield losses under drought conditions (Senbayram *et al*., 2015). Qin *et al.* (2008) studied the role of various nutrients including magnesium on yield and quality of field tomatoes and resulted in 10% enhanced yield with the combined use of nutrients fertilizers. Similar results were obtained by Osman and El-Sawah (2009) who investigated the influence of foliar magnesium application on two tomato cultivars grown under field conditions and concluded that foliar treatment of magnesium increased total chlorophyll content and yield as compared to control. In another field experiment, foliar application of magnesium under high temperature conditions increased total fruit yield of tomato cultivars compared to control (El-Sayed *et al*., 2010). Kasinath *et al.* (2014) studied the effect of calcium and magnesium fertilizers applied to field grown tomatoes and recorded an enhanced fruit yield with 100kg mg ha^{-1}. However further increase in magnesium decreased the yield and produced antagonistic influence on calcium uptake. Bombiti Nzanza (2006) also reported an increased yield of tomato when calcium magnesium ratio was kept at 15:5 respectively.

A field as well as hydroponic research study on improving yield and quality of tomatoes with boron treatment proved that boron application enhanced total yield as well as marketable yield when compared with no boron application considerably due to interaction with other nutrients and enhanced boron translocation in phloem tissues (Davis *et al*., 2003). Huang and Snapp, (2009) studied the influence of boron and potassium nutrition on enhancement of fruit quality of tomato and noted that boron foliar application enhanced yield as well as fruit quality. Similar findings were reported by Sahin *et al.* (2015) who investigated the interactive effect of boron and calcium on growth and quality of tomato and noted an increased yield as well as quality of tomato fruit. Our results are also in accordance with Rab and Haq (2012) who concluded maximum number of fruits per plant and yield of tomato when treated with foliar application of calcium and boron. Furthermore, Singh *et al.* (2007) carried out experiments to explore the role of foliar application of calcium and boron on fruit quality and yield of strawberry and recorded an increased fruit yield in plants treated with calcium and boron foliar application as compared to control. Similar results were also reported by Shnain *et al.* (2014) who worked on foliar treatment of boron and zinc on growth, quality and yield of tomato and concluded that combined application of boron and zinc enhanced various vegetative and reproductive attributes including plant height, number of leaves and total yield.

Conclusions

On the basis of results of this experiment, it is concluded that the combined application of 5kg ha^{-1}mg + 2kg ha^{-1} B resulted in increased morphological and reproductive attributes. It was also noted that enhanced vegetative and reproductive growth was recorded in tomato cultivar Rio Grande and is therefore, recommended for cultivation in the agro climatic conditions of Peshawar, Khyber Pakhtunkhwa-Pakistan.

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