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Research Article

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Effect of foliar spray of gibberellic acid (GA_3) and borax on growth, productivity, and quality of tomato (*Lycopersicon esculentum* Mill.) under protected structure at Kaski, Nepal

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ABSTRACT
Tomato (*Lycopersicon esculentum* Mill.) is a highly demanded solanaceous vegetable crop in Nepal. Poor vegetative growth, low flowering and fruit set are the major problems in tomato. Thus, an experiment was conducted to improve vegetative growth, flowering, fruiting and productivity of tomato (Nepali Variety Type 2) at Pokhara-14, Kaski, Nepal during spring- summer of 2019 in Split plot arrangement with gibberellic acid (GA3) as main factor and Borax as sub factor, with three replications. The main factor consisted of four concentrations of GA_3 (0, 25, 50 and 75 ppm) which was applied thrice as foliar spray at 15, 30 and 45 days after transplanting (DAT) and sub factor consisted three concentrations of borax (0%, 0.25% and 0.5%) which was applied four times as foliar spray at 15, 30, 45 and 60 DAT. Growth characters viz., plant height, leaf area, leaf number, flower number per cluster, fruit number were significantly enhanced with application of 50 ppm GA_3 and gave higher productivity (31.65 t ha^{-1}) compared to other concentrations and control. Likewise, foliar spray of borax resulted in higher stem girth, flower clusters, number of flowers per cluster, and TSS content of tomato. Furthermore, borax @ 0.25% gave the highest productivity (30.78 t ha^{-1}). The better effect of 50 ppm GA_3 on growth and yield of tomato and effect of 0.25% borax on flowering and yield, makes them promising solutions to the problems of tomato at Kaski, Nepal. Thus, further research should be conducted by using GA_3 and borax in several other tomato cultivars in field and under protected structure at different soil type and climatic conditions.
Keywords: boron; gibberellic acid (GA3); productivity; tomato.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) belonging to the Solanaceae family, grows 1-3 meters in height and has a weak stem that often sprawls over the ground and vines over other plants. It is perennial in its native habitat, often grown outdoors as a seasonal crop. It originated in the South American Andes and spread throughout the world (Bhandari *et.al.*, 2015). Tomato is the 8th most valuable crop worldwide. In 2019, the global production of tomatoes totaled 180 million tons (FAOSTAT, 2019). It is a highly demanded solanaceous vegetable crop in Nepal which fetches a more reasonable price compared to other vegetables. As it has great demand throughout the year, it is grown in both winter and summer seasons. In Nepal it is grown in 21,389 hectares of land in and the total production is approximately 400,674 tons. Likewise, in Kaski district it is grown in 400 hectares with total production of 6,231 tons (MOAD, 2018). It is widely grown in an open field as well as closed protected structures like tunnels and greenhouses in Nepal. While open field cultivation during Autumn-Winter is common in Terai, inner Terai and foothills, cultivation inside greenhouse in Summer-Rainy season in hills is getting popular (Bhandari *et.al.*,2015)

Protected structure is the most contemporary approach to produce horticultural crops qualitatively and quantitatively and has extensively spread over the world in the last few decades (Janick, 1979). The hailstone rampage at Kaski causes heavy damage to crops worth millions of rupees. Moreover, in a region like Kaski, where there is frequent heavy rainfall and hailstones, it is the best alternative to grow vegetables. Regardless of available fertile land, protected structure and irrigation facilities for production and possible marketing of tomato in Kaski, the production is low due to physical and biological factors (Gelmesha *et.al.*,2013). Due to stunted vegetative growth and excessive blossom drop, the productivity of tomato is decreasing many folds and has become major issue.

There is extensive use of plant growth regulators (PGRs) in horticulture because it is known to enhance plant growth and improves yield by increasing fruit number, fruit set and size (Batlang, 2008). The natural occurrence of GA_3 in plants in minute quantities is known to control plant's growth, thus effect of spray of gibberellic acid (GA_3) at very low concentrations can be beneficially exploited. It is a common phytohormone used commercially for improving the productivity and quality of the number of crop plants (Janick, 1979). Boron is a micronutrient, that affects quality of tomato fruit particularly size and shape, color, firmness, TSS, keeping quality and chemical composition (Mangalhaes *et.al.*,1980). The soluble form is often recommended at 45-to-113.4-gram ha^{-1} for vegetable crops. It is very toxic to plants if applied in excess so applying at the correct dose is critical (Earnest, 2016). The initiation of tomato fruit growth and fruit set is very sensitive to environmental conditions but there is little understanding on the role of Gibberellic Acid (GA3) that regulates this process and facilitates the production. It is therefore highly worthwhile to explore possible ways to enhance the productivity of tomatoes employing cost effective and easy to use techniques.

MATERIALS AND METHODS

The experiment was conducted during February to May at a protected structure at the Kham Ghale farm, Chauthe, Pokhara Metropolitan City ward 14, Kaski, Nepal. The geographical location of the research site was about 28º 2622' N Latitude and 84º 0167' E Longitude. From the analysis, soil pH was found to be neutral (pH 6.8) in the experimental field. The nitrogen content and organic matter was low whereas available phosphorus and available potassium was higher in range based on a rating chart to determine the fertility of the experimental site. Likewise, the soil was deficit in boron and there was moderate amount of zinc in the soil. The research site lied in the sub-tropical zone of Nepal, which was characterized by three distinct seasons namely, monsoon (June – October), cool winter (November – February), and hot summer (March – May).

Tomato of variety "Nepali variety type 2" manufactured by company SATIVA Rhein, Switzerland was used. The fruits were round, red having average diameter of 3 cm and germination percentage of 80 percent. The experiment was carried out in split plot arrangement with GA_3 (0, 25, 50 and 75 ppm) as main factor and foliar spray of borax (0, 0.25 and 0.5 %) as subplot factor. The seeds were sown under protected conditions in a poly-pot tray. The field was ploughed twice followed by planking and the seedlings were transplanted with spacing of 45 cm * 60 cm P-P * R-R after 27 days after sowing.

For Gibberellic acid,1 gram of Gibberellic Acid (GA_3) was weighed using electronic balance and was kept in a flask. N/10 NaOH was added dropwise until the GA_3 was dissolved and stirred using a magnetic stirrer. The pH of the solution was checked using a pH meter and was made neutral by adding N/10 HCl dropwise. After the pH was neutral, the solution was made 1000 ml by adding distilled water that is 1000ppm stock solution of GA_3. The different concentrations (0, 25, 50, 75 ppm) was made using the stock solution. Likewise, for a borax concentration of 0.25%, 2.5gram borax was weighed and dissolved in distilled water by the help of an electromagnetic stirrer. The solution was made to 1000ml. 0.5 % borax formulation was made in a similar way.

Twenty tons FYM was applied into the field as a basal dose and recommended dose of N: P: K @ 200:180:80 $kgha^{-1}$ was applied. Nitrogen was given in three equal splits by top dressing. After transplanting of seedlings, various intercultural operations such as irrigation, weeding, and staking was performed. Irrigation was done through drip irrigation system as per plant requirement. Harvesting was done manually and fruits were harvested at 3days interval during the early ripe stage when they attained a slight red color. Five randomly selected plants in each plot were tagged for observations and characters were studied in the successive stages of crop growth. The observation recorded were plant height, leaf area, number of fruits per plants, individual fruit weight and productivity. The height of five tagged plants in each plot was measured in cm with the help of meter scale from 30 days after transplanting at an interval of 15 days and then mean plant height was calculated. For leaf area, length and width of largest leaf, medium leaf and small leaf of five randomly selected plants was measured and average was calculated. Then, the leaf area of plant was calculated using formulae:

Leaf area = 0.347*(Length*width)-10.7 (Blanco *et.al.*,2003).

Number of fruits was recorded by counting the total harvested fruit at different days of harvest. Five fruits from each sample plant were selected randomly. The total weight per plant was recorded at the time of harvesting and the average weight per fruit was calculated. The yield was recorded by weighing the fruits harvested from each plot in different pickings and the TSS was determined using a handheld refractometer in degree brix. Different statistical tools such as GEN-STAT and MS-EXCEL were used for the analysis of variance and data analysis. The data was analyzed, and findings were discussed and related with available literature.

RESULTS AND DISCUSSION

Plant height (cm)

Significant effect on height was obtained due to various concentrations of GA_3 at 45 and 60 DAT. Among different concentrations, GA_3 @ 75 ppm resulted in the tallest plant height (75.27 cm) which was statistically at par with the effect of GA_3 @ 25 and 50 ppm. The smallest plant height (48.05cm) was obtained at 0 ppm GA_3 at 45 DAT. Similar trends was obtained in the height of tomato plants at 60 DAT. According to Rai *et.al.*, (2012), it might be because of GA_3 on cell division and enlargement in sub-apical meristem. Gibberellins cause plants to grow taller by stimulating cell elongation. Since plants are composed of single cells stacked on top of one another, this elongation of thousands of individual cells results in overall growth of the plant (DJ, 1995). Height of the tomato plant was not statistically influenced by borax concentration. The highest plant height was obtained at 0 % borax.

Table 1. Height of tomato plant as affected by Gibberellic acid (GA3) and Borax at different days after transplanting at Chauthe, Kaski, 2019.

Treatments	Plant height (cm)		
	30 DAT	45 DAT	60 DAT
Gibberellic Acid (GA_3)			
0 ppm	24.56	48.05^{b}	68.77^{c}
25 ppm	30.42	63.24^{a}	91.09^{b}
50 ppm	34.16	66.27^{a}	99.56^{ab}
75 ppm	35.84	75.27^{a}	106.09^{a}
SEm (±)	2.335	3.439	3.539
LSD (0.05)	NS	11.90**	12.24**
CV (%)	12.9	9.4	6.7
Borax			
0%	31.88	64.67	91.65
0.25%	30.58	62.0	90.73
0.5%	31.28	62.95	91.74
SEm (±)	0.980	1.228	1.732
LSD (0.05)	NS	NS	NS
CV (%)	10.9	6.7	6.6
Grand mean	31.24	63.21	91.38

Means followed by common letter(s) within the column are non- significant based on DMRT at P=0.05. NS, Non-significant; LSD, Least significant difference; SEM, Standard error of Mean; CV, Coefficient of Variation; DAT, Days After Transplanting, DAT, Days After Transplanting

Leaf area (cm^2)

Leaf area due to different concentration of treatments was found to be statistically significant. At 30 DAT, different concentration had significant difference in leaf area. Largest leaf area (79.8cm^2) was obtained at 50 ppm GA_3 which was statistically at par with the effect of 75 ppm GA_3. The lowest leaf area (67.9cm^2) was obtained at control and 25 ppm concentration gave the intermediate leaf area (76.9cm^2). At 45 DAT the leaf area was highly affected by different concentrations of GA_3 where the highest area (190.4cm^2) was found at the plants treated with 75 ppm GA_3 followed by the leaf area (163.2cm^2) treated by 50 ppm GA_3. The lowest leaf area (121.2cm^2) was obtained at control. The intermediate leaf area was obtained at the plant sprayed with 25 ppm GA_3. At 60 DAT significantly largest leaf area (474cm^2) was recorded @ 75 ppm which was statistically at par with 25 and 50 ppm GA_3. Significantly the smallest leaf area (359cm^2) was obtained at control. The results might be the effect of GA_3 on cell division, elongation that is obtained by the increase of cellular permeability, which helps to increase the flow of water and soluble substances within the cell, thus increasing cell size (Lateef *et.al.*,2018). Significant effect due to borax on leaf area was recorded at 60 DAT. The largest leaf area (461.3cm^2) was obtained at 0.25 % borax treatment and the smallest leaf area (415.1cm^2) area was obtained at the control treatment which was statistically at par with the effect of 0.5% borax.

Table 2. Leaf area of tomato plants as affected by Gibberellic acid (GA3) and Borax at different days after transplanting at Chauthe, Kaski, 2019.

Treatments	Leaf area (cm^2)		
	30 DAT	45 DAT	60 DAT
Gibberellic Acid (GA_3)			
0 ppm	67.9^{c}	121.2^{d}	359.0^{b}
25 ppm	76.9^{b}	145.9^{c}	444.5^{a}
50 ppm	83.9^{a}	163.2^{b}	460.3^{a}
75 ppm	79.8^{ab}	190.4^{a}	474.4^{a}
SEm (±)	1.75	4.52	13.32
LSD (0.05)	6.05**	15.64***	46.11**
CV (%)	3.9	5.0	5.3
Borax			
0%	76.4	154.8	415.1^{b}
0.25%	77.9	156.7	461.3^{a}
0.5%	77.0	154.1	427.3^{b}
SEm (±)	2.22	3.05	0.298
LSD (0.05)	NS	NS	0.893*
CV (%)	10.0	6.8	8.9
Grand mean	77.1	155.2	434.5

Means followed by common letter(s) within the column are non- significant based on DMRT at P=0.05. NS, Non-significant; LSD, Least significant difference; SEM, Standard error of Mean; CV, Coefficient of Variation; DAT, Days After Transplanting.

Number of fruits per plant, Individual fruit weight (gm) and Productivity (t ha^{-1})

Fruit number per plant was significantly affected by the application of GA_3. Number of fruits was recorded to be the highest (56.19) @ 50 ppm GA_3. The lowest number (50.67) was obtained @ 0 ppm GA_3 and intermediate number (53.87) was recorded at 25 ppm GA_3 which was statistically at par with effect of 75 ppm GA_3. It might be due to that Gibberellic acid that enhances fruit setting in tomatoes (Serrani *et.al.*, 2007), but increasing concentration of GA_3 might reduce the number of fruits per plant. Borax had a significant influence on the number of fruits per plant. The highest fruit number per plant (55.17) was recorded @ 0.25% borax which was statistically similar with the effect of 0.5% borax. The result might be due to optimum boron concentration, as boron plays an important role in maintaining cell integrity, improving respiration, enhancing metabolic activities and uptake of nutrients (Rai *et.al.*,2012). According to Jackson (1991), without the presence of boron pollen tube germination was completely inhibited at temperature over 21ºC.

Individual fruit weight (gm)

GA_3 had no significant influence on individual fruit weight. However, the maximum weight of single fruit was obtained at treatment of 75 ppm GA_3 followed by 50 ppm and 25 ppm. Minimum weight was obtained at control. Alternately, the effect of foliar application of borax significantly differed the individual fruit weight of tomato plants. At harvest, individual fruit weight was significantly higher (15.29g) when 0.25 % borax was applied. The minimum weight (13.48g) was obtained at control i.e., 0 % borax which was statistically similar with effect of 0.5% borax. This might be since boron involved in the division and expansion of cells, improved the volume of intracellular space in mesocarp cells in addition to quicker translocation of metabolites into the sink (fruits) (Bramhachari *et.al.*, 2001).

Productivity (t ha^{-1})

Productivity of tomato plants varied significantly due to application of various concentrations of GA_3. The highest yield (31.65 t ha^{-1}) was obtained at treatment of 50 ppm GA_3. Lowest yield (27.82 t ha^{-1}) was obtained from control which was statistically at par with the effect of 25 and 75 ppm GA_3. According to the experiment conducted by Sultana (2013), the application of GA_3 @ 50 ppm increased plant height, number of leaves, number of flower clusters per plant, number of flowers per cluster, number of fruit clusters per plant, fruit diameter, fruits weight and thus the overall yield of tomato. Foliar application of different concentrations of borax also had significant differences in the yield potential of tomato plants. Highest productivity (30.78 t ha^{-1}) was obtained at the borax concentration of 0.25 % followed by 29.38 mt/ha at 0.5% borax. The lowest productivity (27.55 t ha^{-1}) was obtained at control treatment. The increase in yield potential might be due to continued supply of food material and water since boron helps in absorption of water and carbohydrate metabolism (Gelmesa *et.al.*,2013). Similar results were obtained by Rab and Haq (2012).

Table 3. Number of fruits per plant, individual fruit weight and productivity of tomato as influenced by GA_3 and Borax at Kaski, Nepal, 2019

Treatments	Fruit number	Individual fruit weight (g)	Productivity (t/ha)
Gibberellic Acid (GA_3)			
0ppm	50.67^c	13.70	27.82^b
25ppm	53.87^b	13.95	28.32^b
50ppm	56.19^a	14.76	31.65^a
75ppm	53.80^b	14.85	29.15^b
SEm (±)	0.538	0.455	0.713
LSD (0.05)	1.863**	NS	2.467*
CV (%)	1.7	5.5	4.2
Borax			
0%	51.61^b	13.48^b	27.55^b
0.25%	55.17^a	15.29^a	30.78^a
0.5%	54.61^a	14.18^b	29.38^a
SEm (±)	0.705	0.315	0.517
LSD (0.05)	2.114**	0.945**	1.551**
CV (%)	4.6	7.6	6.1
Grand mean	53.80	14.32	29.23

Means followed by common letter(s) within the column are non- significant based on DMRT at P=0.05. NS, Non-significant; LSD, Least significant difference; SEM, Standard error of Mean; CV, Coefficient of Variation; DAT, Days After Transplanting

Total soluble solid content (º Brix)

There was no significant difference in TSS contents of tomato fruits due to application of various concentrations of GA_3 but was significantly influenced by application of different concentrations of borax as compared to control. The highest TSS content (6.33° Brix) was recorded with the treatment 0.5% borax which was statistically at par with the result of 0.25 % borax. The lowest TSS content was obtained at control treatment. This result agrees with the findings of Kumuthini and Vellupillai, 2015 [13]. Higher TSS content might be attributed to the efficient translocation of photosynthates to fruit by regulation of boron (Trivedi *et.al.*,2012). According to Marschner (1995), Boron increases the movement of phloem carbohydrates, which increases soluble solid content.

Table 4. Total Soluble Solids content (º Brix) of tomato plant as affected by Gibberellic Acid (GA_3) and Borax at Kaski, Nepal, 2019

Treatments	Total soluble solids content (º Brix)
Gibberellic Acid (GA_3)	
0 ppm	6.06
25 ppm	5.62
50 ppm	6.04
75 ppm	6.58
SEm (±)	0.203
LSD (0.05)	NS
CV (%)	5.8
Borax	
0%	5.80^b
0.25%	6.10^{ab}
0.5%	6.33^a
SEm (±)	0.137
LSD (0.05)	0.413*
CV (%)	7.9
Grand mean	6.081

Means followed by common letter(s) within the column are non- significant based on DMRT at P=0.05. NS, Non-significant; LSD, Least significant difference; SEM, Standard error of Mean; CV, Coefficient of Variation; DAT, Days After Transplanting

CONCLUSION

Foliar application of GA_3 increased plant height, leaf area, leaf number, flower number per cluster, fruit number of tomato plant. Further, application of 50 ppm GA_3 gave higher productivity compared to other concentrations and control. Foliar spray of borax resulted in higher stem girth, flower clusters, number of flowers per cluster, TSS content of tomato. Further, borax @ 0.25 % gave highest productivity of tomatoes under protected structure. No interaction effect of GA_3 and borax was reported on all recorded parameters.

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