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Effect of silicon on quality and nutritional properties of Tomato fruit yield (*Lycopersicum esculantum*) var. Rajitha grown under water stress condition

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Abstract: *Tomato (Lycopersicum esculantum) in Sri Lanka is much lower production than the world normal as the climate changes negatively influence by normal production. Silicon assumes essential part in plant tolerance to environment stresses. Silicon application helpful to enhance the water stress resistance of tomato through the improvement of water uptake capacity. This experiment was aimed to determine the effect of application of Silicon (in different amount) on quality and nutritional parameters of yield of Tomato under water stress condition. Variety Rajitha was selected as it is resistant to bacterial wilt and leaf curl virus. Treatments of the experiment are 75mg/Si and no water stress (T1), 75mg/Si and water stress 50% (T2), 150mg/Si and no water stress (T3), 150mg/Si and water stress 50% (T4), no Si and No water stress (T5), no Si and water stress 50% (T6). A pot experiment was conducted for a period of 6 months at a plant house located in Horticultural Crop Research and Development Institute. The experimental design was a Complete Randomized Design (CRD) with factorial treatment structure. There are 6 treatments and 5 replicates. Water stress and Silicon were taken as factors. Silicon was added as MgSiO3 (Magnesium silicate) and water stress was imposed by maintaining a moisture level equivalent to 50% of field capacity. The results of this experiment showed that the water stress reducing the quality and nutritional parameters of yield of Tomato. The findings of this experiment showed that the application of magnesium silicate at the rate of 75mg and 150mg have a positive influence on yield, quality and nutrients uptake as well as water tolerance effect on tomato var. Rajitha under the water stress conditions compared to the no magnesium silicate application. Further research needs to find the different ways of application of silicon to improve the crop growth under the water stress condition as well as other biotic and abiotic stress. Different sources of Silicon supplement can have to use as silicon fertilizer like sodium silicate, potassium silicate, calcium silicate and silicic acid. Further silicon supplement is used as mulch like rice hull. It is also necessary to conduct experiments with other varieties of Tomato.*

Key words: Water stress, Silicon, Tomato, Quality, Nutritional parameters.

1 INTRODUCTION

Temperature related extreme records have expanded over most areas in Sri Lanka. Yearly normal precipitation over Sri Lanka has been decreased throughout the previous 57 years at a rate of around 7 mm for each year. Amid *yala* season the environmental change will have huge effects on soil moisture conditions and irrigation need and water preservation are important in dry and intermediate zones in Sri Lanka (De Silva, 2006). In the whole plant, response to water stress involves different mechanisms, ranging from stomatal closure to root/shoot ratio increase, leaf area reduction, and osmotic adjustment. In the physiological mechanism of drought avoidance, maintenance of favorable water status in plants achieved through either efficient stomatal regulation or high root activity (Kaya *et* *al*., 2006). Tomato in Sri Lanka is much lower than the world normal as the regular climate changes unfavorably influence normal production (Dishani and De Silva, 2016). Silicon is the second most plenteous component in the world's crust. Si assumes an essential part in plant resistance to natural burdens. Silicon beneficial affects numerous harvests, for the most part under the biotic and abiotic stress. Abiotic factors like dry spell, water logging, low and high temperature UV light, heavy metal, salinity give the real impediment to trim creation around the world. Both biotic and abiotic stress can reduce average plant productivity by 65% to 87% depending on the crop. Therefore, there is need of stress resistance in plant (Mauad *et al*., 2016). The effect of Si on the greater tolerance of higher plants to drought could be associated with an increase in the action of antioxidant defenses, reduction in the oxidative damage to functional molecules and membranes, and maintenance of many physiological as well as photosynthetic processes under water stress conditions (Mauad *et al*., 2016). This study was conducted to investigate the effectiveness of Si in reducing the adverse effects of water stress and thereby increasing the quality and nutritional parameters of Tomato yield.

2. METHODOLOGY

2.1. Location

A pot experiment was conducted for a period of 6 months at a plant house located in Horticultural Crop Research and Development Institute (HORDI), Peradeniya and the experiments were repeated. Variety Rajitha of Tomato was selected as it is resistant to bacterial wilt and leaf curl virus.

2.2. Experimental design

The experiment was arranged in Complete Randomized Design (CRD) with factorial treatment structure (Figure 1). There were 6 treatments and 5 replicates (Table 1). Stress and Silicon were taken as factors. Total population is 30 plants.

Table 1: Treatments of the experiment

Treatments	Composition
T1	75mgSi+ No water stress (WW 100%)
T2	75mgSi + water stress (WS 50%)
T3	150mgSi + No water stress (WW 100%)
T4	150mgSi + water stress (WS 50%)
T5	No Si +No water stress (WW 100%)
T6	No Si+ water stress (WS 50%)

Figure 1. Experimental arrangement inside the Plant House.

2.3. Statistical Design

Data analysis was done by Analysis of Variance (ANOVA) and mean separation was done by LSD using appropriate SAS (University version) procedures.

2.4. Cultural Practices

A pot experiment was conducted for a period of 6 months at a plant house located in Horticultural Crop Research and Development Institute (HORDI), Peradeniya. Plant house has thermostat and air circulation fans. Plant house was maintained temperature at 28^0C. Relative humidity was measured day by day with RH meter but there was no significant difference. Recommended tomato seeds were obtained at vegetable division in HORDI. Silicon was added as $MgSiO_3$ (Magnesium Silicate). According to the treatment order magnesium silicate added to soil surface in pots and mixed and the water stress plant root zone was covered using polyethylene.

2.5. Water management

Water stress was imposed by maintaining a soil moisture level equivalent to 50% of field capacity (FC), whereas the well-watered pots (control) were maintained at full field capacity (100%FC). Field capacity was measured by using two methods; core sampling method and volume basis method but in this experiment only volume basis method values were used. Plant available water for the water stress of 50% soil moisture deficit level was calculated by the difference between field capacity and permanent wilting point moisture content and dived by 2. Plant received irrigation only when plant available water (PAW) is depleted by 50% in water stress plants (Dishani and De Silva, 2016). The water-deficit treatments were applied for 3-week age tomato plants. Every day the water stress and plant water stress level were measured using tensiometer.

2.6. Quality parameters

2.6.1. Leaf relative water content

Leaf relative water content (LRWC) was measured (Kaya *et al.*, 2006) by collecting 2nd or 3rd leaf of the main shoot per replicate and then weighed to obtain fresh mass (FM). In order to determine the turgid mass (TM), whole leaves were floated in distilled water. During the imbibition period, leaf sample were weighed periodically after the water is gently wiped from the leaf surface with tissue paper. At the end of the imbibition period, leaf samples were placed in a preheated oven at 80 °C for 48 hrs to obtain dry mass (DM). All mass measurements were done using an analytical balance with precision of 0.0001g. Values of FM, TM, and DM were used to calculate LRWC using the following equation.

$$RWC\ (\%) = [(FM - DM) / (TM - DM)] \times 100$$

2.6.2. Fruit diameter

Fruit diameter (mm) was measured by using centimeter rule and average diameter was measured.

2.6.3. Fruit length

Fruit length (mm) was measured by using centimeter rule and average fruit length was calculated.

*2.6.4. Total soluble solid*s

Total soluble solid was measured using digital refractometer and result was expressed as Brix value (Gunawardena and De Silva, 2015). Tomato fruit per replicate were selected and two slices were taken. The slice was squeezed longitudinally to get a juice. The prepared fruit juice was placed on to refractometer prism plate an equal number of drops. The reading on the prism scale was noted to one decimal place. After each test prism plate was cleaned for next sample.

2.6.5. Firmness

Tomato fruit firmness was determined on two fruits per replicate using hand penetrometer (Fruit pressure tester, model FT-327). Tomato fruit firmness (kg) was measured at the equatorial surface for each individual tomato fruit (Caroline, 2011).

2.6.6. Tomato fruit keeping quality

Fruit keeping quality (days) was determined when tomato fruits started showing signs of shriveling and decay (Caroline, 2011)

2.7. Nutritional parameters

The whole plant samples were cleaned without soil particles and dried at 70 °C. The samples were cut into small pieces and ground in a mill fitted with 1mm screen size sieve. After grinding, the samples were made ash at 500 °C in a muffle furnace. Then P, K, Ca and Mg contents of the plant sample was determined from the ash extract. The open digestion method was used for P, K, Ca and Mg. For that 0.5g weighted oven dry ash sample was taken in to a kjeldahl tube. After that added 2ml H_2O_2 and concentrated HNO_3 and placed the tubes on digestion block in 170 °C heat for 5hours. Then kept it to cool and after that removed to the 100ml volumetric flask and added 100ml distilled water. Next filtered the sample using no. 42 filter paper (Lu *et al* 2016).

2.7.1. Phosphorus analysis

Phosphorus in tomato fruit measured by using Vanadomolybdate method.

2.7.2. Potassium analysis

Potassium in tomato fruit was measured by flame photometer method.

2.7.3 Calcium analysis

Ca contents were determined by ethylenediaminetetraacetic acid (EDTA) method.

2.7.4. Magnesium analysis

Mg contents were determined by ethylenediaminetetraacetic acid (EDTA) method.

2.8. Yield

Fruit yield (kg) was measured in each replicate by using weighing balance and average fruit yield was measured.

3. RESULTS AND DISCUSSION

3.1. Fruit yield

Based on the results significantly highest fruit yield was collected in no water stress 150mg Si treatment plants (1.4kg) followed by no water stress 75mg Si treatment plants (1.173kg) and no water stress no Si treatment plants (1.146kg). Lowest fruit yield was collected in water stress no Si treatment plants (0.707kg). However, among the water stress treatments 150mg Si treatment plants (0.967kg) recorded the significantly highest fruit yield and water stress 75mg Si treatment plants (0.77kg) followed it. These results indicated that water stress negatively effect on fruit yield (Figure 2). Results also showed tomato plants reproductive processes were negatively affected by the water stress condition and water stress in the early growth period decreased the number of flowers leading to a reduced in the number of fruits and yield. Caroline (2011) showed that the reduction in fruit weight and diameter under stress conditions may contribute to the reduction in fruit yield. This experiment results agree with that findings of reductions in fruit yield in the water stressed plants compared to the no water stressed plants. And also, there was a reduction in the yield in all water stress treatment plants but application of magnesium silicate has increased the yield under water stress condition. Similar results obtained by Jarosz (2014) that the higher total fruit yield in the treatments fertilized with the silicon enriched nutrient solution the total fruit yield of sand grown tomato was lower compared to that of plants grown in Rockwool and also Meena *et al*,. (2014) indicate that the application on silicon fertilization to increased crop yield in tropical soils and observed that the silicon application may be one of the available resource for increased crop growth and crop yield in arid or semi-arid areas. Magnesium silicate improves the other nutrient because of that silicon applied plants were higher yield than other treatments. This study agrees with the findings of Lalithya *et al.*, (2014) at the time of fruit harvest minimum nutrients were available in the soil and maximum uptake of nutrients were showed in the silicon treated treatment and observed maximum yield in sapota fruits.

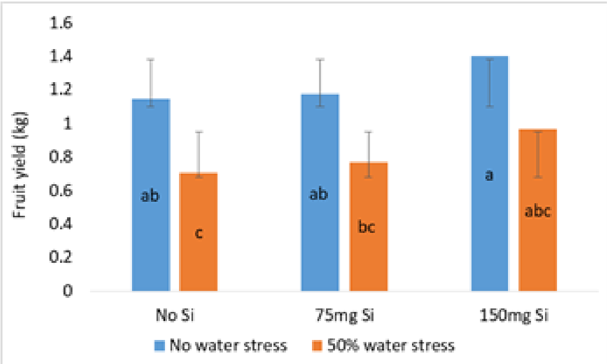

Figure 2: Effect of treatments on fruit yield

3.2. Quality parameters

3.2.1. Leaf relative water content (LRWC)

As shown in Figure 3, the highest leaf relative water content (LRWC) of tomato plants was observed in no water stress 150mg Si treatment plants (83.23%) and it is not significantly different from 75mg Si no water stress treatment plants (83.04%) and also no Si no water stress treatment plants (82.1%). Among water stressed treatments, significantly highest LRWC was observed in 150mg Si applied plants (56.3%) followed by 75mg Si applied treatment plants (55.7%). Significantly lowest LRWC was observed water stress no Si treatment plants (54.4%). This may be because water stress decreases the plant growth and quality. But there was some difference of leaf relative water content between the silicon applied plants and no silicon applied plants. Similar results were obtained by Lobato *et al* (2009) that the leaf relative water content (LRWC) of treatments under silicon application was maintained at levels closer to the control treatment, because silicon was probably absorbed by plant, and deposited in epidermal cell wall. And also, the silicon can contribute to higher resistance of xylem vessels and that vessels are structures responsible by water transport within tomato plant. Silicon uptake plants with firmer xylem vessel walls can potentially avoid problems in these structures during water stress. In this experiment magnesium silicate improved the LRWC in tomato plant than no silicon applied treatment. Results are also similar to the findings of Hattori *et al* (2007) as the application of silicon could affect stomatal conductance through the modification of plant water status but not through any physical changes. Gong *et al* (2003) found silicon increase in leaf relative water content and an increase in leaf water potential of wheat in drought conditions.

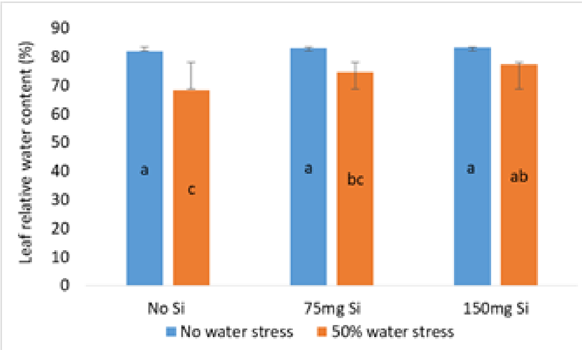

Figure 3: Effect of treatments on leaf relative water content

3.2.2. Fruit diameter

Significantly highest fruit diameter was observed in no water stress 150mg Si treatment plant fruits (60mm) followed by no water stress 75mg Si treatment plant fruits (59mm) and no water stress no Si treatment plants fruits (55mm) (Figure 4). Lower fruit diameter was observed in water stress treatments but water stress 75mg Si treatment plant fruits (49mm) and water stress 150mg Si treatment plant fruits (51mm) were have better fruit diameter than water stress no Si treatment plant fruits (44mm). Water stresses are negatively impact on fruit diameter. There was a reduction in the fruit diameter in all water stressed treatment plants, but silicon increases the fruit diameter even under water stress condition. Highest fruit diameter among water stressed treatments was observed in 150mg Si treatment plant fruits. Several changes in plant growth and developmental processes are often observed in plants that are exposed to water stress overtime because photosynthesis and transpiration are inhibited immediately after receiving the water stress and also water stress in the early growth period decreased the number of flowers leading to a reduction in the number of fruits and also fruit diameter. Similar results were observed by Sibomana *et al* (2013) that water stress decreased fruit diameter compared to the no water stress treatment plant fruits, but application of silicon increase fruit diameter in water stress treatments. In this experiment result indicates magnesium silicate application increased the tomato fruit diameter under the water stress condition.

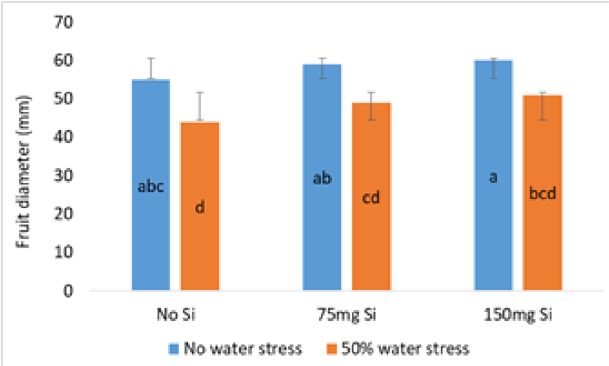

Figure 4: Effect of treatments on fruit diameter

3.2.3. Fruit length

According to the results shown in Figure 5, highest fruit length observed in no water stress 150mg Si treatment plant fruits (50mm) and it is not significantly different from no water stress 75mg Si treatment plant fruits (45mm). Among water stress treatments, significantly lowest fruit length (35 mm) was observed in no Si treatment but 75mg Si treatment plant fruits (41mm) and 150mg Si treatment plant fruits (40mm) have higher fruit length. Water stress negatively effect on fruit diameter and fruit length because of water stress condition reduce the water uptake as well as nutrient uptake by tomato plants but in this experiment application of magnesium silicate improve the tomato fruit length under water stress condition.

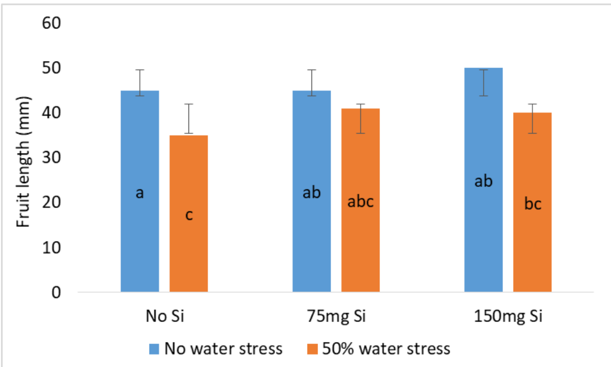

Figure 5: Effect of treatments on fruit length

3.2.4. Total soluble solid (TSS)

According to the results shown in Figure 6, significantly highest total soluble solid (TSS) was observed in water stress 150mg Si treatment plants fruits (4.7) followed by 75mg Si treatments plant fruits (4.3) and no Si water stress treatment plant fruits (4.2). TSS was higher in water stressed plant fruits than no water stress plant fruits. Among no water stress treatments 150mg Si treatment plant fruits (4.6) shown higher TSS than 75mg Si treatment plant fruits (3.4) and no water stress no Si treatment plant fruits (3.3). Water stress resulted in decreased yield compared to the no water stress treatments in tomato but water stress increased TSS value. Water stress improved water uptake by the tomato plants and therefore lead to the dilution of the concentration of TSS. Lowest TSS values are showed in no water stress treatments. This results are in accordance with results reported by Caroline (2011) in tomato fruits, no water stress can be attributed to the higher water uptake by the plants and therefore increase the dilution of the concentration of TSS. This study showed that higher levels of TSS were found in fruits from stressed plants. It has been widely shown that reduced soil moisture increases sugar content in tomatoes. But in this experiment magnesium silicate has contributed to water stressed plant fruits positively in TSS than no water stress plant fruits. Das *et al*.(2017) has explained in his experiment that the decrease in acidity might be due to increase in the TSS and it was because of silicon involved in fast conversion of metabolites into sugar and their derivatives and data also similar to Marodin *et al* (2016) and Nuruddin *et al* (2003). They have indicated that water stress improved the quality of fruits and increased TSS. Further, this experiment results have indicated that the application of magnesium silicate contributed positively in both water stress and no water stress condition by increased TSS level compared to the no silicon applied treatments plants.

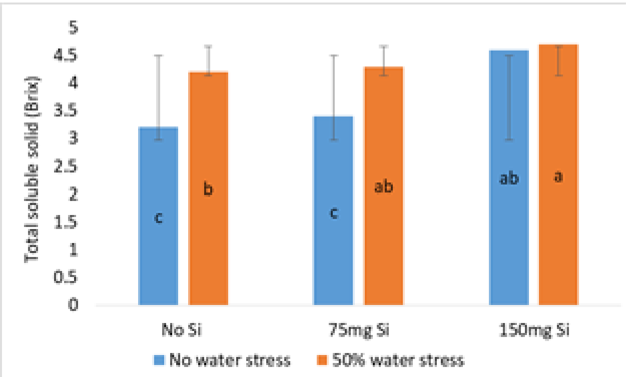

Figure 6: Effect of treatments on total soluble solid (TSS)

3.2.5. Firmness

According to the results shown in Figure 7, significantly highest firmness was observed in 150mg Si water stress treatment plant fruits (6.3kgf) followed by 75mg Si water stress treatment plant fruits (5.94kgf) and no Si water stress treatment plant fruits (5.54kgf). Among no water stress treatment fruits highest firmness was observed in 150mg Si treatment plant fruits (5.34kgf) followed by 75mg Si treatment plant fruits (4.72kgf) and no Si treatment plant fruits (4.3kgf). This results showed water stress resulted in increased firmness in fruits and also Silicon resulted in increased fruit firmness. Firmness is the most important indices used in determining the best time to harvest tomato fruit for, storage, transportation and marketing. Firmness is also important to fruit quality as it is directly related to tomato fruit growth, maturity, ripening and storage potential. Fruit firmness is most affected by water content. Water stress condition increased the fruit firmness similar and result indicated by Caroline (2011). In this experiment results showed that the application of magnesium silicate increased the tomato fruits firmness highly in water stress treatment and also improves the firmness in no water stress condition. Similar result found by Dattatray (2018) and he found that the quality parameters were increased with soil and foliar application of silicon compared to control and he revealed that application of foliar application of potassium silicate improving the quality parameters which agrees and with the results found by Alkarim *et al* (2017) in cucumber fruits.

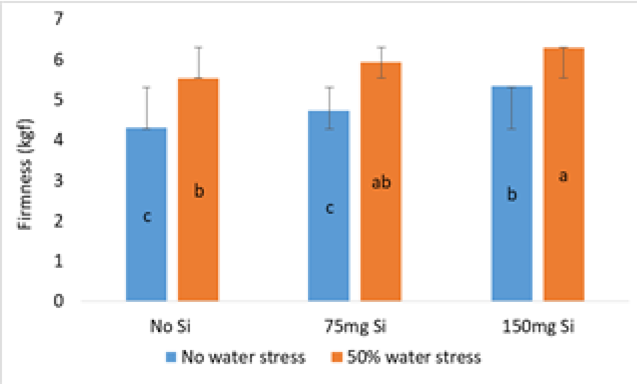

Figure 7: Effect of treatments on firmness

3.2.6. Fruit keeping quality

According to the results shown Figure 8 significantly highest fruit keeping quality was observed in no water stress 150mg Si treatment plant fruits (21days) followed by no water stress 75mg Si treatment plant fruits (17days) and no water stress no Si treatment plant fruits (18days). Significantly lowest fruit keeping quality was observed in water stress no Si treatments plant fruits but water stress 75mg Si treatment plant fruits (16days) and water stress 150mg Si treatment plant fruits (17days) were have better fruit keeping quality than water stress no Si treatment plant fruits (15days). Magnesium silicate has resulted in increased the fruit keeping quality in both water stressed, and no water stressed conditions. These results agreed with Mohommad *et al* (2018) and also Islam *et al* (2015). They found that the effects of foliar spraying of silicon confirm the quality and shelf life of cherry tomatoes.

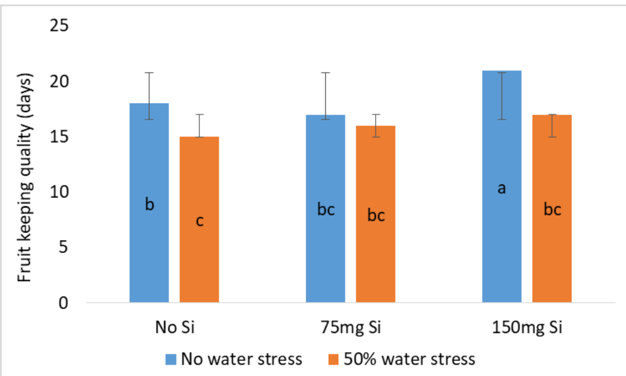

Figure 8: Effect of treatments on fruit keeping quality

3.3. Nutritional parameters

3.3.1. Phosphorus content in Tomato fruits

According to the results shown in Figure 9, significantly highest phosphorus level was observed in no water stress 150mg Si treatment plants (2.0%) and followed by no water stress 75mg Si treatment plants (1.8%) and no water stress no Si treatment (1.6%). Significantly lowest phosphorus level was observed in water stress no Si treatment (0.5%). Among the water stress treatments highest phosphorus percentage was observed in 150mg Si treatment plants (1.4%) followed by 75mg Si treatment plants (0.7%). Water stress affects the phosphorus uptake by plants. Similar results were observed by Neto *et al* (2006) and he found that the salt stress decreases the osmotic potential of soil solution causing water stress, harmful impacts on the plants bringing about damage on the metabolism and nutritional disorders and lack of nutrient uptake. In this experiment results indicated that the magnesium silicate applied treatment increased the phosphorus uptake by tomato plants. Similar results were found by Sahebi *et al* (2015) and he indicated silicon is one of the most prevalent macro elements, performing an essential function in healing plants in response to environmental stresses. Silicon minimizes toxicity of elements and increases the availability of P, and enhances water stress along with tolerance in plants through the formation of silicified tissues in plants. Pulz *et al* (2008) found same results that calcium and magnesium silicate fertilization increased phosphorus content in water stressed potato.

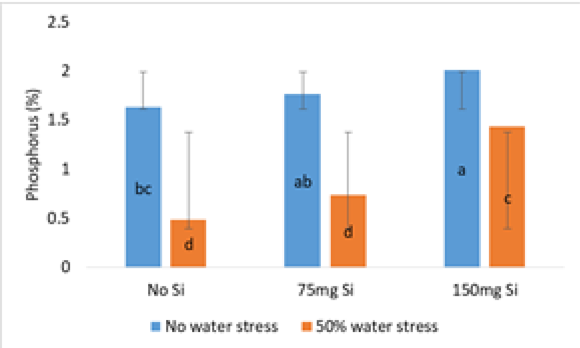

Figure 9: Effect of treatments on phosphorus level

3.3.2. Potassium content in Tomato fruits

According to Figure 10, highest potassium level observed in no water stress 150mg Si treatment plant fruits (0.866ppm) and no water stress 75mg Si treatment plant fruits (0.766ppm) and also no water stress no Si treatment plants fruits (0.633ppm). Lower potassium level observed in water stress treatments but water stress 75mg Si treatment plant fruits (0.5ppm) and water stress 150mg Si treatment plant fruits (0.7ppm) were have better potassium level than water stress no Si treatment plant fruits (0.433ppm). These results indicated that the water stress reduce the uptake potassium by tomato plants, but application of magnesium silicate improve the nutrient uptake by plants. Similar result found by Satisha *et al* (2017) nutrient contents were partitioned into leaves, shoot, roots and fruits and result showed that the uptake of potassium substantially higher in plants with silicon Liang (1999) also found that the K plays an essential role in processes involving osmotic adjustment and its adequate level in plants may improve water stress tolerance under water stress conditions, silicon may result in better supply of potassium.

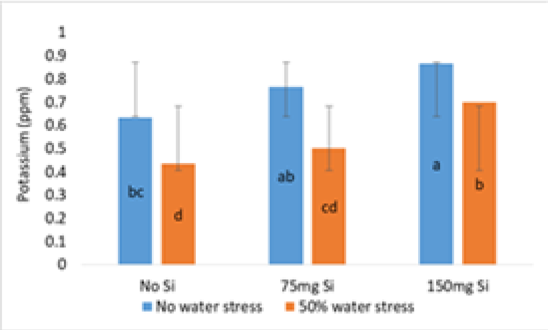

Figure 10: Effect of treatments on potassium level

3.3.3. Calcium content in Tomato fruits

According to the results shown in Figure 11, significantly highest Calcium content was observed in no water stress 150mg Si treatment plant fruits (5.3ppm) followed by no water stress 75mg Si treatment plants (4.5ppm) and no water stress no Si treatment (4.0ppm). Among the water stress treatments highest Calcium content was observed in 150mg Si treatment plant fruits (4.2ppm) followed by 75mg Si water stress treatment plant fruits (3.4ppm). Significantly lowest Calcium content was observed in water stress no Si treatment (2.9ppm). According to the results observed that the water stress negatively affects the Ca uptake by plant but magnesium silicate applied treatment increased calcium level. Similar result found by Das *et al.*, (2017) and he showed that the presence of silicon also been reported to affect the absorption and translocation of several macro and micronutrients and also observed silicon is accumulated in plants to total concentrations in dry matter similar to those of essential macro-nutrients such as Potassium, Calcium, Magnesium, Sulphur and Phosphorous. Kaya *et al* (2006) showed that addition of silicon may increase concentrations of calcium in plant tissues and hence restore membrane integrity in water stressed plants.

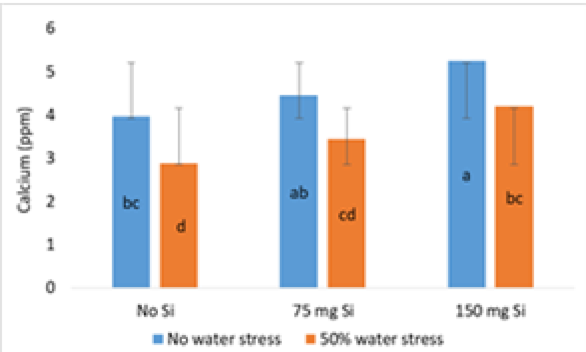

Figure 11: Effect of treatments on Calcium level

3.3.4. Magnesium content in Tomato fruits

According to the results shown in Figure 12, significantly highest Magnesium content was observed in no water stress 150mg Si treatment plant fruits (3.2ppm) followed by no water stress 75mg Si treatment plant fruits (2.7ppm) and no water stress no Si treatment plants fruits (2.4ppm). Lowest Magnesium content was observed in water stress treatments but water stress 75mg Si treatment plant fruits (2.3ppm) and water stress 150mg Si treatment plant fruits (2.5ppm) have shown higher Magnesium content than water stress no Si treatment plant fruits (2.3ppm). In this experiment results indicate the water stress condition reduces the magnesium uptake by tomato plants, but application of silicon increased the magnesium level in plants than no silicon applied tomato plants. Similar results were found by Das *et al*., (2017) and he indicated that the presence of silicon affects the absorption and translocation of several macro and micronutrients and also silicon is accumulated in plants to total concentrations in dry matter similar to those of essential macro-nutrients such as magnesium. Gunes *et al*., (2008) also found that the application of Si under water stress condition significantly improved magnesium uptake by plants.

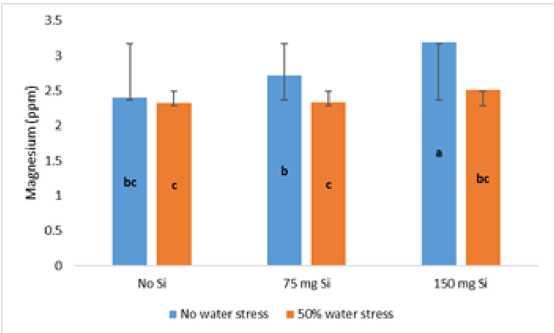

Figure 12: Effect of treatments on Magnesium level

4. CONCLUSIONS AND RECOMMENDATIONS

The aim of this experiment was to determine the effect of silicon on quality and nutritional properties of yield of tomato (*Lycopersicum esculentum*) var. Rajitha under water stress condition. The results showed water stress have some positive effect of tomato fruit quality parameter like TSS and Firmness. The findings of this experiment showed that the application of magnesium silicate have a positive influence on yield, quality and nutrients uptake as well as water tolerance effect on tomato var. Rajitha under the water stress and also under no water stress conditions. Further research needs to find the different ways of application of silicon to improve the crop growth under the water stress condition as well as other biotic and abiotic stress. Different sources of Silicon supplement can have to use as silicon fertilizer like sodium silicate, potassium silicate, calcium silicate and silicic acid. Further silicon supplement is used as mulch like rice hull. It is also necessary to conduct experiments with other varieties of Tomato.

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