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Response of soil and foliar application of silicon on physiological parameters of sweet orange (*Citrus sinensis L.* Osbeck) Cv.Nucellar

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Abstract

The field study entitled ‘‘Response of soil and foliar application of silicon on growth and yield parameters of sweet orange (*Citrus sinensis* L. Osbeck) Cv. Nucellar.” was carried out at Sweet Orange Research station, Badnapur, Dist. Jalna during 2017-18.The experiment was laid out in Randomized Block Design (RBD) with 13 treatments and three replication. Observations were recorded on fruit set ,fruit drop ,transpiration rate, photosynthesis rate and stomatal index. The maximum fruit set (%)**,** minimum fruit drop (%) was observed in the treatment T_4. .(foliar application of potassium silicate @ 8 ml/lit) Whereas, the minimum fruit set (%), maximum fruit drop (%) was recorded in the treatment T_1(control). . The treatment T_4.(foliar application of potassium silicate @ 8 ml/lit) recorded the lowest transpiration rate during April and May month. Whereas, T_1(control). recorded the highest transpiration rate. The treatment T_4.(foliar application of potassium silicate @ 8 ml/lit) recorded the highest photosynthesis rate during April and May month. Whereas, T_1(control). recorded the lowest photosynthesis rate. No significant difference was observed in stomatal index which clearly indicated that there was no impact of various treatments on stomatal index in sweet orange.

1.Introduction

Citrus fruits are the one of the world’s most important fruit crop and are consumed mostly as fresh produce, juice, squashes, cordial and pickles. Citrus fruits have many merits. They are available throughout the year.

They are not only delicious and refreshing to eat, but also provide vitamins, minerals and many other essential substances, which are required for human health. They are specially important for growing children and are an important source of vitamin ‘C’, which plays a vital role in prevention of scurvy.

The total area of sweet orange in India is 278 thousand ha with production 4526 MT. (Anonymous 2015). Commercially, Sweet orange, mandarin and acid lime are grown in different agro-climatic regions. Andhra Pradesh, Maharashtra, Karnataka, Punjab, Haryana, and Rajasthan are the main sweet orange growing states. Maximum area under sweet orange is in the Andhra Pradesh followed by Maharashtra and Karnataka.

Maharashtra is the largest producer of sweet orange in the country and contributes to about 49 per cent of the total production. Maharashtra state produces 0.65 m MT sweet orange from an area of 0.11 m ha with the productivity of 6.1 MT/ha. The major sweet orange producing belts in the state are

Ahmednagar, Aurangabad, Jalna, Jalgaon, Amravati and Pune (Anonymous 2013).

Silicon is one of the abundant elements in the lithosphere and it is the most abundant element in soil next to oxygen and comprises 28 per cent of its weight and 3 - 7 per cent in soil solution (Epstein, 1999). It is most commonly found in soils in the form of solution as silicic acid (H_4SiO_4) and plants take up directly as silici acid (Ma, *et al*., 2001). The silicon supply is mainly depended on silicon supplying ability of the soil. Supplemental application of silicon increased the shoot silicon concentration and leads to dry matter production (Prakash, *et al*., 2011).

The role of exogenous silicon in enhancing plant resistance to various abiotic stresses : salinity , drought , metal toxicity and ultra violet radiation (Balaknina and Borkowska, 2013). Silicon spraying improved growth and physiological indices hence could increase the ability of plants to resistance water stress. Silicon application reduces transpiration leads to water stress tolerance (Asgaripour and Masapour, 2016). Silicon is the second most abundant element in the soil next to oxygen. However, still it is not recognized as an essential element for plant growth but the undeniable beneficial effects of this element on the growth and development have been observed in a wide variety of plant species. The role of silicon in plant biology is to reduce multiple stresses including biotic and abiotic stresses
Soil salinity and drought are major abiotic factors that limit crop growth and productivity worldwide. Silicon application could therefore improve crop production under adverse climate and soil conditions. (Zhu and Gong, 2014) Hence,considering the need , the present investigation study on Response of soil and foliar application of silicon on physiological parameters of sweet orange (*Citrus sinensis* L. Osbeck) Cv. Nucellar.has been conducted.

2. Material and Methods

The experiment was conducted during 2017-18, on uniform 8 years old plants of cv. Nucellar mosambi planted at the spacing of 6x6m at the Sweet Orange Research Station, Badnapur, district Jalna of Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. Station is situated at 409 m above mean sea level at 19.87°N latitude and 75.72°E longitudes with an altitude of 523 meters. The average rainfall of the station is about 650 mm received mostly during June to September. The mean minimum and maximum temperature during the last five years were 15.25^{0}C and 43.85^{0}C and the mean relative humidity ranges from 30 to 90 percent and rainfall in the year 2017 is 662 mm. Experiment was laid out in a Randomized Block Design (RBD) with three replication and thirteen treatments these are of control (T_1), foliar application of potassium silicate @ 4 ml/ lit (T_2), foliar application of potassium silicate @ 6 ml/ lit (T_3), foliar application of potassium silicate @ 8 ml/lit (T_4), Soil application of calcium silicate @ 1kg/plant (T_5), soil application of calcium silicate @ 1.5 kg/plant (T_6), soil application of calcium silicate @ 2 kg/plant (T_7), foliar application of potassium silicate @4 ml/ lit + soil application of calcium silicate @ 1kg/plant (T_8), foliar application of potassium silicate @ 6ml/ lit + soil application of calcium silicate @1kg/plant (T_9), foliar application of potassium silicate @ 4 ml/ lit + soil application of calcium silicate @ 1.5 kg/plant (T_{10}), foliar application of potassium silicate @ 6 ml/ lit + soil application of calcium silicate @ 1.5 kg/plant (T_{11}), foliar application of potassium silicate @ 4 ml/ lit + soil application of calcium silicate @ 2 kg/plant (T_{12}), foliar application of potassium silicate @ 6 ml/lit + soil application of calcium silicate @ 2 kg/plant (T_{13}).

The Badnapur area is dominated by black soil formed from basalt rock originated through volcanic eruption belongs to order vertisols. The soil is dominant in montmorillonite followed by moderate amount of kaolinite and traces of ellite. The soil properties of Sweet Orange Research Station, Badnapur are Sand - 26%, Silt - 33%, clay - 33%. Field capacity - 36%, PWP - 17 %, Bulk Density- 1.34 (g/cc) , pH - 8.1, EC- 0.39 (mmhos/cm),Calcium carbonate- 9.5%, Organic carbon- 0.48%, Available P_2O_5- 27(Kg ha^{-1}), Available K_2O- 340 (Kg ha^{-1}), Available sulphur - 7.0 (ppm) ,DTPA Zn- 0.56 (ppm), DTPA Fe- 3.4 (ppm) and HWS Boron- 0.50 (ppm).

Fruit set per cent was calculated by counting total number of flowers of individual plant and the number of flowers converted/ setted into fruit.
Fruit set (%) = [Total number of fruits / Total number of flowers] × 100.

The set fruit from above flowers were used for studying the intensity of fruit drop up to the time of harvesting and percentage were worked out.

$$\text{Fruit drop (\%)} = \frac{\text{(Total number of fruit set – No. of fruits at harvest time)}}{\text{(Total no. of fruit set)}} \times 100.$$

The photosynthesis rate was measured by Advance Photosynthetic System *GFS-3000* (WALZ, Germany). Gas exchange measurements were made between 10:00 and 11:30 h (IST) on sunny and generally cloud free days. For measuring A, stomatal conductance (gs) and Transpiration rate

(E) in light, photosynthetic leaf chamber (*model*: GFS-3010-S) was clipped onto the attached leaf, which had been exposed to sunlight. The chamber was held in such an angle that the enclosed leaf surface faced the sun, to avoid the shading inside the cuvette. The irradiance at the upper surface of the leaf chamber was measured by calibrated sensor (filtered silicon photocell, *model*: 3055-FL) mounted on the same surface of the leaf chamber. It was 1300 ± 50 µmol m^{-2} s^{-1} outside during the most photosynthesis measurements. The temperatures were 35.1 ± 2°C; relative humidity was 55 ± 2%; CO_2 concentration 378 ± 15 µmol CO_2 mol^{-1} in control. Measurements were made from five different plants with fully expanded leaf at periphery of fruits area. According to Caemmerer and Farquhar (1981) the photosynthesis rate (A) was calculated as follows:

$$A = \frac{u_e \text{ x } (c_e - c_o)}{LA} - (E \; x \; c_o)$$

Where,

A = assimilation rate (photosynthesis rate) [µmol m^{-2} s^{-1}],

u_e = molar flow rate at the inlet of the cuvette [µmol s^{-1}],

c_o = CO_2 mole fraction at the outlet of the cuvette [ppm],

c_e = CO_2 mole fraction at the inlet of the cuvette [ppm],

LA = leaf area [cm^2], and

E = transpiration rate [mmol m^{-2} s^{-1}].

Stomatal index is the percentage which the number of stomata forms to the total number of epidermal cells, each stomata being counted as one cell. Stomatal index was calculated by using following equation (Royer, 2001).

$$SI\ (\%) = \frac{\text{Stomatal density}}{\text{Stomatal density} + \text{epidermal cell density}} \; x \; 100$$

3. Results and Discussion

The observations were recorded on various aspects viz, fruit set, fruit drop, transpiration rate, photosynthesis rate and stomatal index, The observations recorded during the investigation are presented and discussed as below.

3.1 Fruit set (%)

The maximum fruit set (%) (12.30%) was observed in the treatment T_4.(foliar application of potassium silicate @ 8 ml/lit) and it was statistically at par with T_3 (12.06%), T_9 (11.91%). Whereas, the minimum fruit set (8.59 %) was recorded in the treatment T_1.which is presented in table 1. Silicon application helped in improving fruit set and minimizing fruit drop of sweet orange. Maximum fruit set (12.30%) and minimum fruit drop (59.34%) were observed in treatment T_4 (foliar application of potassium silicate @ 8 ml/lit) This results are in accordance with results reported by El- Gioushy (2016) in Washington Navel Orange tree.

3.2. Fruit drop (%)

The minimum fruit drop (59.34%) was observed in the treatment T_4 and it was statistically at par with T_3 (60.43%). Whereas, the maximum fruit drop (65.82 %) was recorded in the treatment T_1. presented in table 1. The maximum values of these parameters were recorded such as the maximum increase in height of tree (0.48 m), maximum increase in East-West spread (0.60 m), regarding North-South plant spread the maximum increase (0.68 m), the maximum increase in canopy volume (17.37 m^3) were observed in the treatment T_4.(foliar application of potassium silicate @ 8 ml/lit). Potassium silicate had positive effect on growth Increased growth might have attributed due to increased photosynthetic activity of plant, water metabolism, chlorophyll content, more formation of carbohydrates, membrane lipid peroxidation, protective enzymes under drought condition and more uptake of essential nutrients. Similar results were noticed by Roshdy (2011) in Grandnaine banana.

Table 1 : Effect of different treatment of silicon on fruit set, fruit drop of sweet orange.

Sr. No.	Treatment No.	Fruit set (%)	Fruit drop (%)
1	T_1	8.59	65.82
		-17.03	**-54.2**
2	T_2	10.57	63.78
		-18.96	**-52.98**
3	T_3	12.06	60.43
		-20.32	**-51**
4	T_4	12.3	59.34
		-20.52	**-50.36**
5	T_5	9.73	64.61
		-18.17	**-53.47**
6	T_6	11.27	62.41
		-19.6	**-52.16**
7	T_7	10.12	64.34
		-18.54	**-53.32**
8	T_8	11.62	61.85
		-19.92	**-51.84**
9	T_9	11.91	61.53
		-20.18	**-51.65**
10	T_{10}	10.75	63.33
		-19.13	**-52.71**
11	T_{11}	11.4	62.05
		-19.72	**-51.95**
12	T_{12}	11.11	62.93
		-19.46	**-52.47**
13	T_{13}	10.86	63.01
		-19.23	**-52.52**
14	S.E. ±	0.15	0.23
15	C.D at 5%	0.45	0.68

3.3. Transpiration rate (E):

Among the treatments studied, T_4 recorded the lowest transpiration rate (1.72 mmol m^{-2} s^{-1}) followed by T_3 (1.86 mmol m^{-2} s^{-1}) and T_9 (2.05 mmol m^{-2} s^{-1}) during April month. Whereas, T_1 recorded the highest transpiration rate (2.93 mmol m^{-2} s^{-1}) during April month.

While in May month, T_4 recorded the lowest transpiration rate (1.94 m mol m^{-2} s^{-1}) followed by T_3 (2.12 mmol m^{-2} s^{-1}) and T_9 (2.28 mmol m^{-2} s^{-1}) during May month. Whereas, T_1 recorded the highest transpiration rate (3.32 mmol m^{-2} s^{-1}) during May month.

3.4. Photosynthesis rate (A):

The results showed that among the treatments, T_4.(foliar application of potassium silicate @ 8 ml/lit) recorded the highest photosynthesis rate (5.18 µmol m^{-2} s^{-1}) followed by T_3 (4.98 µmol m^{-2} s^{-1}) and T_9 (4.97 µmol m^{-2} s^{-1}) during April month. Whereas, T_1 recorded the lowest photosynthesis rate (4.22 µmol m^{-2} s^{-1}) during April month.which is presented in table 2

While in May month, T_4 recorded the highest photosynthesis rate (4.28 µmol m^{-2} s^{-1}), it was at par with T_3 (4.26 µmol m^{-2} s^{-1}) , T_9 (4.25 µmol m^{-2} s^{-1}) during May month. Whereas, T_1 recorded the lowest photosynthesis rate (3.86 µmol m^{-2} s^{-1}) in May month.

3.5. Stomatal Index (SI):

The results on stomatal index (SI) of various treatments in sweet orange are presented in Table 2. The analysis of results pointed out that there were statistically no significant differences observed which clearly indicated that there was no impact of various treatments on stomatal index in sweet orange. The lowest transpiration rate (1.72 mmol m^{-2} s^{-1} , 1.94 mmol m^{-2} s^{-1}) , the highest photosynthesis rate (5.18 µmol m^{-2} s^{-1} , 4.28 µmol m^{-2} s^{-1}) in April and May month respectively were observed in the treatment T_4. There are various physiological processes of plants which are affected by water stress, with cell growth probably the most sensitive. Moosavi *et al*. (2014) revealed from their results that the reduction in plant height, LAI and number of umbels per plant under water stress could be attributed greatly to photosynthesis impairment and decline in photosynthetic products to transmit to the growing parts of plant. Further, they reported that water stress reduces plant height, LAI and number of umbels per plant in fennel. It is proven that Si through modification of plant water relation stimulates cell division and cell elongation (Na and Jiashu, 2001) boosts plant immune system (Liang *et al*., 2007) and enhances plant growth. The application of silicate in different forms and results obtained from our experiment indicated that silicate increases the LAI and photosynthesis under water stress condition as compare to control. Similar results obtained by Mohaghegh *et al.* (2010). The present study is an initiative made to understand the problem of water stress and the remedial impact of silicate on sweet orange to increase the production under projected climate change scenario and more research is required to abridge the research gap on this aspect. There were statistically no significant differences observed which clearly indicated that there was no impact of various treatments on stomatal index in sweet orange.

Table 2: Effect of different treatment of silicon on transpiration rate, photosynthesis rate, stomatal index of sweet orange.

Sr. No.	Treatment No.	Transpiration rate (E) (mmol $m^{-2}s^{-1}$)		Photosynthesis rate(A) (µmol $m^{-2}s^{-1}$)		Stomatal index (SI)
		April	May	April	May	May
1.	T_1	2.93	3.32	4.22	3.86	19.73
2.	T_2	2.53	2.91	4.30	3.92	16.93
3.	T_3	1.86	2.12	4.98	4.26	16.63
4.	T_4	1.72	1.94	5.18	4.28	16.68
5.	T_5	2.62	3.00	4.26	3.88	20.17
6.	T_6	2.36	2.71	4.85	4.21	17.61
7.	T_7	2.55	2.93	4.28	3.90	18.57
8.	T_8	2.27	2.61	4.95	4.24	18.34
9.	T_9	2.05	2.28	4.97	4.25	18.27
10.	T_{10}	2.50	2.84	4.80	4.14	17.94
11.	T_{11}	2.32	2.56	4.93	4.22	19.27
12.	T_{12}	2.37	2.72	4.84	4.21	17.45
13.	T_{13}	2.45	2.69	4.82	4.20	18.27
14.	S.E. ±	0.01	0.02	0.01	0.01	1.19
15.	C.D at 5%	0.03	0.06	0.03	0.03	NS

4. Conclusion

The maximum fruit set (%) was observed in the treatment T_4 and it was statistically at par with the treatments T_3. Whereas, the minimum fruit set (%) was recorded in the treatment T_1. The minimum fruit drop (%) was observed in the treatment T_4 and it was statistically at par with T_3 . Whereas, the maximum fruit drop (%) was recorded in the treatment T_1.

The treatment T_4 recorded the lowest transpiration rate followed by T_3 and T_9 during April month. Whereas, T_1 recorded the highest transpiration rate. While in May month , T_4 recorded the lowest transpiration rate followed by T_3 and T_9 during May month. Whereas, the treatment T_1 recorded the highest transpiration rate during May month.

The treatment T_4 recorded the highest photosynthesis rate followed by T_3 and T_9 during April month. Whereas, T_1 recorded the lowest photosynthesis rate during April month. While in May month, T_4 recorded the highest photosynthesis

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rate, it was at par with the treatments T_3, T_9 during May month. Whereas, T_1 recorded the lowest photosynthesis rate in May month. There were statistically no significant differences observed in stomatal index which clearly indicates that there was no impact of various treatments on stomatal index in sweet orange.

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