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Effect of silicon and seaweed extract on plant growth and leaf nutrient content of papaya cv. Red Lady

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Abstract
A study was carried out during 2016-17 and 2017-18 at Instructional Farm, ACHF, Navsari Agricultural University, Navsari with a view to assess the effect of silicon and seaweed extract on growth and fruiting of papaya cv. 'Red Lady'. The experiment was evaluated in a Randomized Block Design with eleven treatments and replicated thrice. Plants were sprayed with different concentrations of silicon (potassium silicate and ortho silicic acid at 0.2 and 0.4%) and seaweed extract (2 and 4%) either alone or in combinations at 3, 4, 5 and 6 months after planting. The best results with regard to growth parameters *i.e.* plant height, stem girth, number of leaves per plant and leaf area were obtained by spraying plants with potassium silicate at 0.4% + seaweed extract at 4%. It also recorded the maximum leaf nitrogen, phosphorus and potassium content after seven months of planting.

Keywords: Silicon, seaweed extract, growth, leaf nutrient content

Introduction
Papaya (*Carica papaya* L.) has emerged as one of the choicest fruit crop in the tropical and subtropical regions of the world. It is believed to have originated from Tropical America and was introduced to India in 16th century from Malacca (Kumar and Abraham, 1942) [1]. It belongs to family *Caricaceae*. In India, it is successfully grown all over the country and is available round the year. In India, major papaya growing states include Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh and Tamil Nadu. Gujarat is the second largest producer of papaya in the country contributing about 21% to the total production.

Papaya is a highly cross pollinated, dicotyledonous and polygamous plant. Red Lady (F_1 Hybrid) is a gynodioecious cultivar, which is famous among Indian farmers due to its high yielding potential, exceptional quality and long shelf life. Papaya is a heavy feeder and needs heavy doses of manures and fertilizers. The commercial production of papaya is hampered by various biotic and abiotic factors. Silicon is the second most abundant element after oxygen in our soils. It can help in improving plant growth by correcting their deficiencies especially in highly weathered soil of tropical regions. It has positive growth effect including increased dry mass and yield, enhanced pollination and most commonly increased disease resistance (Gillman *et al.*, 2003) [2].

The application of seaweed extract which contains most nutrients, organic compounds, enzymes, vitamins, antioxidants, amino acids and natural hormones is fast becoming an accepted practice. It increase yield quantitatively and qualitatively in various fruit crops (Soliman *et al.*, 2000 and Khan *et al.*, 2009) [3, 4]. At present, there is scanty information about foliar application of silicon and seaweed extract effect on papaya, especially under South Gujarat conditions. Hence, the present investigation was carried out to study the foliar application of silicon and seaweed extract on growth and nutrient content in papaya cv. Red Lady.

Materials and Methods
The present research was conducted at Instructional Farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari during the year 2016-17 and 2017-18. Seven weeks old (15-20 cm height) and healthy seedlings of papaya cv. Red Lady were transplanted on 9th-10th May, 2017 and 14th-15th May, 2018 at a spacing of 2 m x 2 m.

The experiment was laid out in the Randomized Block Design (RBD) with three replications and eleven treatments. The details of different treatments are mentioned below:

T_1: Control
T_2: Potassium silicate 0.2%
T_3: Potassium silicate 0.4%
T_4: Ortho silicic acid 0.2%
T_5: Ortho silicic acid 0.4%
T_6: Seaweed extract 2%
T_7: Seaweed extract 4%
T_8: Potassium silicate 0.2% + Seaweed extract 2%
T_9: Potassium silicate 0.4% + Seaweed extract 4%
T_{10}: Ortho silicic acid 0.2% + Seaweed extract 2%
T_{11}: Ortho silicic acid 0.4% + Seaweed extract 4%

Foliar sprays were done at 3, 4, 5 and 6 months after planting. Recommended dose of fertilizer 200:200:250 g NPK/plant/year was applied at 2, 4, 6 and 8 months after planting (MAP). The growth parameters *i.e.* plant height (cm), stem girth (cm), number of leaves per plant and leaf area (m^2) were recorded at 4^{th}, 6^{th} and 8^{th} months after transplanting from five selected plants of each replication. For estimating the leaf nutrient status of papaya crop, healthy and matured leaf (6^{th} leaf from apex) samples were taken for analysis before foliar application and one month after foliar application (7 MAP) of silicon and seaweed extract. Nutrients were analyzed using following standard methods *i.e.* Wet digestion (Chromic acid) method for N content and Wet digestion (Diacid) method for P & K content. Necessary plant protection measures were undertaken during the course of investigation.

Results and Discussion

Growth parameters

A perusal of data presented in Table-1 and 2 indicate that silicon and seaweed extract did not exert a significant influence on plant height, stem girth and leaf area at 4 MAP during both the years. Further, the number of leaves per plant was found non-significant during both the years at 4 as well as 6 months after planting. Six months after planting, plant height was found maximum (195.53 and 201.00 cm) in treatment T_9 during 2017 and 2018, respectively. It was at par with treatment T_{10} (182.60 cm) during 2017 and with T_{10} (186.93 cm) and T_7 (185.20 cm) during 2018. The maximum plant height (214.67 and 222.20 cm) after 8 months of planting, was recorded again treatment T_9, which was on same bar with treatment T_{10} (205.93 and 216.73 cm) during both the years, respectively.

Stem girth was found maximum (45.13 and 49.13 cm) in treatment T_9 during both the years, respectively and it was on same bar with treatment T_{10} (43.13 cm) during 2017 and with T_{10} (47.27 cm) and T_7 (44.07 cm) during 2018 after 6 months of planting. A similar trend was noted 8 months after planting, as the maximum stem girth (53.07 and 55.80 cm) was noted with treatment T9 during both the years, respectively. It was at par with treatment T_{10} (51.27 cm) during 2017 and with T_{10} (55.20 cm) and T_7 (53.00 cm) during 2018. The minimum values for plant height and stem girth were observed under treatment T_1 (control).

The number of leaves per plant was found maximum (40.73 and 42.90) in treatment T_9 and it was at par with treatment T10 (38.47 and 39.87) and T_7 (37.87 and 39.80) during both the years, respectively after 8 months of planting. Leaf area was recorded maximum (2.49 and 2.55 m2) in treatment T_9 during both the years after 6 months of planting and it was on same bar with treatment T10 (2.42 m2) during 2017 and with T_{10} (2.47 m2) and T_7 (2.41 m2) during 2018. After 8 months of planting, the maximum leaf area (3.95 and 4.03 m2) was registered with treatment T_9 during both the years, respectively. It was at par with treatment T10 (3.84 and 3.99 m2) and T_7 (3.74 and 3.83 m2) during 2017 and 2018. Number of leaves per plant and leaf area was observed minimum in treatment T_1.

Silicon has an important role to play stimulating antioxidant systems within plants as well as immobilization of toxic metals and uptake of essential nutrients. This might have encouraged cell division and biosynthesis of organic foods which could explain the present results (Epstein and Bloom, 2003) [5]. Datnoff *et al*. (2001) [6] opined that silicon application often causes leaves to assume orientations more favorable for light interception and primary metabolism. These results are in agreement with those obtained by Kanto (2002) [7], Gad El-Kareem (2012) [8] in mango and Ibrahim and Al-Wasfy (2014) [9] on Valencia orange with silicon. Seaweed extracts have higher amounts of essential nutrients, amino acids, vitamins and antioxidants, which promote cell division and biosynthesis of organic foods (Norrie *et al*., 2002) [10]. Seaweed also contain plant hormones i.e. auxin, gibberellins especially cytokinins, which have an active role in stimulating plant growth. It might also be due to presence of iron and manganese contents in seaweed extract, which enhance chlorophyll production and photosynthesis processes eventually contributing to positive effects on growth parameters. In addition, seaweed extracts improve nutrient uptake by roots (Crouch *et al*.,
1990) [11], resulting in root systems with improved water and nutrient efficiency, thereby causing enhanced general plant growth and vigor. Ahmed *et al*. (2013) [12] in mango; El-Miniawy *et al*. (2014) [13] in strawberry and Al-Rawi *et al*. (2016) [14] in peach reported similar results with seaweed extract.

Table 1: Effect of silicon and seaweed extract on plant height and stem girth at 4, 6 and 8 MAP in papaya cv. Red Lady

Treatments	Plant height (cm)						Stem girth (cm)					
	4 MAP		6 MAP		8 MAP		4 MAP		6 MAP		8 MAP	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
T_1	127.00	131.93	144.67	147.80	159.73	165.20	25.40	28.13	31.87	37.93	40.00	42.80
T_2	128.53	134.13	152.80	163.40	166.73	181.87	26.47	28.73	35.60	39.33	41.93	43.00
T_3	132.87	136.27	162.27	163.53	185.60	187.80	28.33	29.47	36.80	40.20	42.67	43.40
T_4	139.00	139.73	172.53	177.53	188.40	198.27	30.40	31.00	39.93	43.20	47.20	49.13
T_5	140.47	142.20	171.60	174.40	187.80	197.80	30.27	30.80	39.67	43.73	47.00	49.07
T_6	138.53	138.60	166.73	173.80	189.80	193.47	29.53	30.00	39.27	43.20	46.60	49.20
T_7	141.67	143.93	175.07	185.20	191.33	198.47	32.13	31.47	40.20	44.07	47.27	53.00
T_8	144.73	148.60	169.00	174.00	190.40	193.60	31.40	31.07	40.20	43.87	47.20	49.53
T_9	152.87	156.00	195.53	201.00	214.67	222.20	33.87	34.47	45.13	49.13	53.07	55.80

T_{10}	149.00	153.60	182.60	186.93	205.93	216.73	32.47	32.80	43.13	47.27	51.27	55.20
T_{11}	139.47	141.47	171.73	177.07	190.73	197.87	31.27	30.93	40.20	43.73	47.20	49.73
SEm ±	5.98	8.10	6.90	7.79	7.69	7.98	2.07	1.83	1.66	1.77	1.96	1.99
CD	NS	NS	20.35	22.99	22.70	23.53	NS	NS	4.90	5.21	5.79	5.88
CV%	7.43	9.85	7.05	7.71	7.08	7.06	11.90	10.27	7.33	7.07	7.31	7.03

Table 2: Effect of silicon and seaweed extract on number of leaves per plant and leaf area at 4, 6 and 8 MAP in papaya cv. Red Lady

Treatments	Number of leaves per plant						Leaf area (m^2)					
	4 MAP		6 MAP		8 MAP		4 MAP		6 MAP		8 MAP	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
T_1	19.93	22.07	28.07	29.73	30.13	31.27	1.19	1.23	1.85	1.90	2.50	2.57
T_2	20.53	22.20	28.27	31.20	31.27	33.40	1.21	1.27	1.94	1.98	2.77	2.86
T_3	20.80	23.13	28.47	31.47	31.80	36.27	1.25	1.29	2.08	2.17	2.81	2.93
T_4	21.33	24.13	29.00	32.67	35.73	36.33	1.35	1.37	2.16	2.27	3.04	3.26
T_5	21.47	24.27	28.80	33.80	34.27	37.33	1.33	1.34	2.12	2.24	3.06	3.18
T_6	20.87	23.87	29.13	33.33	34.40	36.27	1.32	1.35	2.10	2.17	2.98	3.01
T_7	21.73	25.80	29.40	34.93	37.87	39.80	1.39	1.42	2.25	2.41	3.74	3.83
T_8	22.07	26.60	29.67	35.13	34.47	36.53	1.34	1.36	2.22	2.26	3.32	3.42
T_9	25.53	28.93	32.53	37.93	40.73	42.90	1.46	1.51	2.49	2.55	3.95	4.03
T_{10}	23.80	27.20	30.80	36.33	38.47	39.87	1.39	1.43	2.42	2.47	3.84	3.99
T_{11}	21.53	25.27	29.20	34.67	34.67	36.33	1.35	1.37	2.23	2.28	3.21	3.32
SEm ±	1.68	1.96	1.55	1.89	1.42	1.67	0.05	0.05	0.07	0.09	0.11	0.13
CD	NS	NS	NS	NS	4.20	4.93	NS	NS	0.21	0.25	0.32	0.38
CV%	13.37	13.63	9.14	9.71	7.07	7.84	6.89	6.48	5.74	6.61	5.83	6.75

Leaf nutrient content

There was no significant difference observed before foliar application of silicon and seaweed extract in major nutrient (N, P and K) content of papaya leaves. Fig. 1 reveals significant differences after foliar application of silicon and seaweed extract. The maximum leaf nitrogen content (2.09 and 2.13%) was recorded in treatment T_9 during 2017 and 2018, respectively. It was at par with treatment T_{11} (2.03%) and T_7 (1.89%) during 2017 and with treatment T_{11} (2.07%), T_7 (2.04%) and T_{10} (1.96%) during 2018. Phosphorus content in papaya leaves was found maximum (0.63 and 0.68%) in treatment T_9, which was on same bar with treatment T_{10} (0.61 and 0.66%) and T_{11} (0.60 and 0.64%) during both the years, respectively. Further, the maximum leaf potassium content (3.69 and 3.77%) was registered with treatment T_9 during both the years and it was at par with treatment T_{10} (3.63%) during 2017 and with T_{10} (3.68%) and T_{11} (3.48%) during 2018. The least value for leaf nutrient content was observed in treatment in treatment T_1.

The significant increase in leaf nutrient content might be due to the fact that seaweed extract contains nutrients especially N, P and K as well as micronutrients, which are absorbed directly when sprayed on the leaves and thus increase in the plant (Singh, 2003) [15]. Seaweed extracts also improve nutrient uptake by roots (Crouch *et al*., 1990) [11] resulting in root systems with improved water and nutrient efficiency. Mohamed and El-Sehrawy (2013) [16] in mango, Ahmed *et al*. (2013) [12] in mango, El-Miniawy *et al*. (2014) [13] in strawberry and Al-Rawi *et al*. (2016) [14] in peach obtained similar results with seaweed extract. Silicon helped in higher uptake of potassium due to its synergistic effect (Lalithya *et al*., 2014) [17]. Silicon in solution rendered more P available to plants reversing its fixation and thus slowly released P and helped in more uptake (Javaid and Misgar, 2017) [18]. These findings are in consonance with those of Bhavya (2010) [19] in Bangalore Blue Grapes, Nesreen *et al*. (2011) [20] in bean and Kumbargire *et al*. (2016) [21] in banana with silicon.

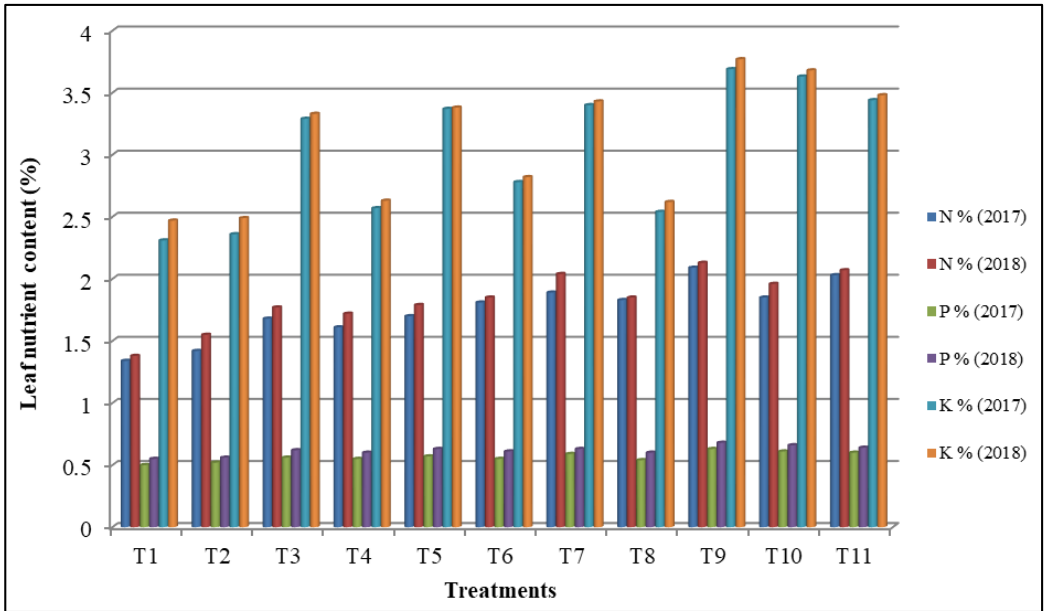

Fig 1: Effect of silicon and seaweed extract on leaf nutrient content of papaya cv. Red Lady

Conclusion

Based on the findings of this study, it can be concluded that foliar application of silicon and seaweed extract at 3, 4, 5 and 6 months after planting on papaya cv. Red Lady grown under South Gujarat conditions had positive effect on growth and leaf nutrient content. The application of potassium silicate at 0.4% + seaweed extract at 4% can effectively improve growth in terms of plant height, stem girth, number of leaves per plant and leaf area and leaf nutrient content i.e. nitrogen, phosphorus and potassium in papaya cv. Red Lady.

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