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Effect of foliar spray of silicon and boron on fruiting and yield of rejuvenated mango (*Mangifera indica* L.) cv. Sonpari

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Abstract
An experiment was conducted at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, during two continuous years 2017-18 and 2018-19 to assess the effect of different silicon and boron sources on fruiting and yield of mango cv. Sonpari under South Gujarat conditions. The experiment was laid out in a Completely Randomized Design with factorial concept having ten treatment combinations comprising five levels of silicon and two levels of boron. Foliar spray of potassium silicate @ 1.5% (S_3) was found better with respect to maximum fruit retention (4.14%), higher number of fruits at marble (11.05) and harvest (1.91) stages per panicle, higher number of fruits per tree (182.00) and yield (64.62kg/tree). Similarly, foliar spray of boric acid @ 1.2g L^{-1} (B_2) gave maximum fruit retention (4.08%), number of fruits at marble (10.56) and harvest (1.78) stages per panicle, number of fruits per tree (172.80) and yield (60.94kg/tree). In interaction effect, combined spray of potassium silicate @ 1.5% + boric acid @ 1.2g L^{-1} (S_3B_2) gave maximum number of fruits per panicle at marble and harvest stages.

Keywords: Mango, sonpari, potassium silicate, silicic acid, boric acid

Introduction
Mango (*Mangifera indica* L.) belongs to family Anacardiaceae is universally accepted as the finest tropical fruit of the world and has been called "King of the fruits". Mango is rightly known as “National Fruit of India” because of its nutritional richness, unique taste, flavour and medicinal importance. It is originated from South East Asia, the Indo-Burma region, in the foothills of the Himalayas (Mukherjee, 1951) [13]. Sonpari is a popular mango hybrid of South Gujarat region and also known as Gujarat Mango Hybrid-1 (GMH-1). It was released in the year 2000 from Agriculture Experimental Station, NAU, Paria (Gujarat). It was developed from Alphonso as female parent and Baneshan as the male parent. Sonpari is heavy yielder and regular in bearing.

Most of the commercial varieties in mango suffer from erratic fruit drop and sometimes only 0.1% of set fruit reach maturity, which often is a consequence of biotic and abiotic stress. Silicon is taken up by the plant in the form of silicic acid (H_4SiO_4) from the soil. The exact role and requirement of silicon are not identified even though it is found beneficial for crop growth, yield and pest and disease suppression (Epstein, 1999) [6]. The role of silicon in plant biology is to reduce multiple stresses including biotic and abiotic stresses (Melo *et al*., 2003) [10].

The main functions of boron are cell wall strengthens and development, cell division, fruit and seed development, sugar transport and hormone development. Boron is directly or indirectly involved in several physiological and biochemical processes during plant growth (Sharma, 2006) [20]. Boron is involved in the reproduction of plants and germination of pollen spikelet (Bolanos *et al*., 2004) [4]. The role of boron in promoting pollen tube growth is well established and positive correlation could be found between B in the plant and number of flowers (O’Niell *et al*., 2004 and Bergmann, 1984) [3].

Material and Methods
The investigation was carried out during the year 2017-18 and 2018-19 at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari

Agricultural University, Navsari, Gujarat. Heading back of mango trees was done in February, 2012 and top worked with Sonpari cultivar in May, 2012. Trees are medium tall, rounded with moderately spreading twigs. In all 30 uniform tress of mango cv. Sonpari were selected for experimentation. All experimental trees were uniformly treated in respect with fertilization, irrigation and plant protection measures during the course of investigation, as recommended by NAU, Navsari.

Trees were planted at a distance of 6m x 6m. The experiment was laid out in a Completely Randomized Design with factorial concept having ten treatment combinations comprising five levels of silicon *viz.*, S_1: no silicon, S_2: potassium silicate @ 1.0%, S_3: potassium silicate @ 1.5%, S_4: silicic acid @ 1.0%, S_5: silicic acid @ 1.5% and two levels of boron *viz.*, B_1: no boric acid and B_2: boric acid @ 1.2g L^{-1} and repeated thrice. The first foliar spray was given at full bloom stage and second at pea stage of mango fruits.

Treatment combinations

S_1B_1: Absolute control (No silicon + No boric acid)
S_2B: Potassium silicate (K_2SiO_3) @ 1.0% + No boric acid
S_3B_1: Potassium silicate (K_2SiO_3) @ 1.5% + No boric acid
S_4B_1: Silicic acid (H_4SiO_4) @ 1.0% + No boric acid
S_5B_1: Silicic acid (H_4SiO_4) @ 1.5% + No boric acid
S_1B_2: No silicon + Boric acid (H_3BO_3) @ 1.2g L^{-1}
S_2B_2: Potassium silicate (K_2SiO_3) @ 1.0% + Boric acid (H_3BO_3) @ 1.2g L^{-1}
S_3B_2: Potassium silicate (K_2SiO_3) @ 1.5% + Boric acid (H_3BO_3) @ 1.2g L^{-1}
S_4B_2: Silicic acid (H_4SiO_4) @ 1.0% + Boric acid (H_3BO_3) @ 1.2g L^{-1}
S_5B_2: Silicic acid (H_4SiO_4) @ 1.5% + Boric acid (H_3BO_3) @ 1.2g L^{-1}

Fruits retained per panicle at harvest were estimated using the following formula and recorded in percentage. Fruit drop per panicle was calculated by subtracting the number of fruits at harvest from the number of fruits at marble stage.

$$\text{Fruit retention (\%)} = \frac{\text{No. of fruits at marble stage} - \text{No. of fruits dropped}}{\text{No. of fruits at marble stage}} \times 100$$

The number of fruits per panicle were counted from all twenty tagged panicles at the time of marble stage and harvest stage of fruit and average was worked out. The number of fruits per tree were counted treatment wise from each experimental tree at the time of harvest. The total produce per tree was weighed and noted treatment wise for each experimental tree at harvest and expressed in kilogram per tree.

The data obtained to all the characters studied under present research work were statistically analysed by the method of Completely Randomized Design (CRD) with factorial concept as described by Panse and Sukhatme (1985). The treatment means were compared by critical differences at five per cent level of probability. The data were transformed wherever necessary.

Results and Discussion

Effect on Fruit Retention

The data regarding on fruit retention (Table-1) as influenced by foliar spray of silicon and boron sources were found non-significant in individual years, but it was found significant in pooled analysis. Significantly maximum fruit retention (4.14%) was observed in S_3 (potassium silicate @ 1.5%) which was statistically at par with S_5 (silicic acid @ 1.5%). Likewise, significantly maximum fruit retention (4.08%) was noticed in foliar spray of boric acid @ 1.2g L^{-1} (B_2) as compared to no spray. All the possible interactions between silicon and boron with year were found non-significant on fruit retention (%) in both the years as well as in pooled analysis. This might be attributed to the essential role of silicon and responding the adverse effects of water stress and disorders on growth and fruiting as well as enhancing the tolerance of the trees to drought, water transport and root development while, boron associated with hormonal metabolism, photosynthate accumulation and water relation, thereby increasing retention of fruits. The results are in conformity with Ahmed *et al*. (2013) [2], Abd El-Rahman (2015) [1], Moawad *et al*. (2015) [12] and Sankar *et al.* (2013) [18] in mango.

Effect on Fruit Yield and Its Attributes

It is evident from the data presented in Table-2 & 3 that number of fruits per panicle at marble and at harvest stages were significantly influenced by foliar application of silicon and boron sources. Maximum number of fruits at marble (11.46, 10.64 and 11.05) and harvest (2.23, 1.60 and 1.91) stages were observed in potassium silicate @ 1.5% (S_3) during both the years and in pooled analysis, respectively. Foliar application of boric acid @ 1.2g L^{-1} (B_2) was gave maximum number of fruits per panicle at marble (10.76, 10.35 and 10.56) and harvest (2.00, 1.55 and 1.78) stages during both the years as well as in pooled analysis, respectively as compared to without spray of boric acid. Interaction between different levels of silicon and boron had significant effect during year 2017-18 and in pooled analysis on number of fruits per panicle at marble stage. Number of fruits per panicle at marble stage was observed maximum (12.23 and 11.94) with combined application of potassium silicate @ 1.5% + boric acid @ 1.2g L^{-1} (S_3B_2) during first year and in pooled analysis, respectively. Significantly maximum number of fruits per panicle at harvest (2.42) was noted in S_3B_2 (potassium silicate @ 1.5% + boric acid @ 1.2g L^{-1}) in 2017-18. However, in second year and in pooled analysis, higher number of fruits per panicle at harvest stage (1.85 and 2.10) was observed in S_5B_2 (silicic acid @ 1.5% + boric acid @ 1.2g L^{-1}) which was at par with S_3B_2 (potassium silicate @ 1.5% + boric acid @ 1.2g L^{-1}). Silicon application might enhance cell division, more nutrients and water uptake and resulted in production of a greater number of fruits. Similar observations were made by Gorecki and Danielski-Busch (2009) [7] in green house cucumber, Nesreen *et al*. (2011) [14] in beans and Stamatakis *et al*. (2003) [21] in tomato. Increased fruit set and number of fruits per panicle at marble and harvest stage due to boron was attributed to stimulation of pollen germination, growth of pollen tube, stimulation of fertilization process and higher synthesis of metabolites (Perez-Lopez and Reyes, 1983) [17]. The results are in conformity with the previous reports of Sankar *et al*. (2013) [18] in mango and Chander *et al*. (2017) [5] in guava.

The data pertaining to number of fruits per tree (Table-4) was significantly affected due to foliar application of silicon sources (potassium silicate and silicic acid) and boron source (boric acid). Maximum number of fruits per tree (181.17, 182.83 and 182.00) was observed in S_3 (potassium silicate @ 1.5%) in both separate years and in pooled analysis, respectively. Correspondingly, higher number of fruits per tree (174.00, 171.60 and 172.80) was obtained in B_2 (boric acid @ 1.2g L^{-1}) in the year 2017-18, 2018-19 and in pooled analysis, respectively. Interaction effect between silicon and boron remained non-significant on number of fruits per tree in both the years and in pooled analysis. Higher number of fruits per tree might be due to the involvement of silicon in water and nutrients uptake, photosynthesis process, water transport and root development and tolerance of plants to biotic and abiotic stresses (Mengel *et al*., 2011; Iwaskai *et al*., 2002 and Melo *et al*., 2003) [8, 10]. Boron helps in translocation of starch to fruit and auxin synthesis. The balance auxin in plant regulates the fruit drop or fruit retention in plants, which altered the control of fruit drop and increased the total number of fruits per tree. Similar results were observed by Sankar *et al*. (2013) [18] in mango, Kavitha (2000) [9] in papaya and Sarolia *et al*. (2007) [19] in guava.

The data (Table-5) clearly indicated that maximum fruit yield was recorded in S_3 (potassium silicate @ 1.5%) during both the years and in pooled analysis (65.44, 63.80 and 64.62kg/tree, respectively), which was statistically at par with S_5 (silicic acid @ 1.5%). Similarly, significantly maximum fruit yield was recorded in B_2 (boric acid @ 1.2g L^{-1}) during both separate years and in pooled analysis (61.60, 60.28 and 60.94kg/tree, respectively) as compared to without spray of boric acid. Interaction effect between silicon and boron was found non-significant on fruit yield in individual years and in pooled analysis. The significant increase in fruit yield is a cumulative effect of increase in number of fruits because of reduction in fruit drop and higher fruit set by the direct and indirect effect of foliar spray of silicon and boron sources. These were promotion of starch formation followed by rapid transportation of carbohydrates in plant. The findings are in consistent with Moawad *et al*. (2015) [12] in mango.

Conclusion

It can be concluded that the combined application of potassium silicate @ 1.5% + boric acid @ 1.2g L^{-1} (S_3B_2) at full bloom stage and pea stage of mango fruit under South Gujarat conditions was found beneficial for superior production of mango cv. Sonpari with higher yield.

Table 1: Effect of silicon and boron on fruit retention of mango cv. Sonpari

Fruit retention (%) at harvest									
Treatments	**2017-18**			**2018-19**			**Pooled**		
	B_1	**B_2**	**Mean (S)**	**B_1**	**B_2**	**Mean (S)**	**B_1**	**B_2**	**Mean (S)**
S_1	3.61 (13.02)	4.20 (17.68)	3.90 (15.35)	3.55 (12.70)	3.88 (15.06)	3.71 (13.88)	3.58 (12.86)	4.04 (16.37)	3.81 (14.62)
S_2	3.64 (13.28)	4.12 (16.95)	3.88 (15.11)	3.59 (13.15)	3.64 (13.47)	3.62 (13.31)	3.62 (13.21)	3.88 (15.21)	3.75 (14.21)
S_3	4.38 (19.32)	4.44 (19.75)	4.41 (19.54)	3.86 (14.88)	3.89 (15.17)	3.88 (15.03)	4.12 (17.10)	4.17 (17.46)	4.14 (17.28)
S_4	3.67 (13.52)	4.30 (18.65)	3.99 (16.09)	3.51 (12.33)	3.89 (15.17)	3.70 (13.75)	3.59 (12.93)	4.09 (16.91)	3.84 (14.92)
S_5	3.88 (15.09)	4.40 (19.34)	4.14 (17.22)	3.77 (14.37)	4.03 (16.27)	3.90 (15.32)	3.83 (14.73)	4.21 (17.80)	4.02 (16.27)
Mean (B)	3.84 (14.85)	4.29 (18.47)	4.06 (16.66)	3.66 (13.49)	3.87 (15.03)	3.76 (14.26)	3.75 (14.17)	4.08 (16.75)	3.91 (15.46)
	B	S	B x S	B	S	B x S	B	S	B x S
S. Em. ±	0.09	0.15	0.21	0.69	1.09	1.55	0.06	0.09	0.13
C. D. at 5%	NS	NS	NS	NS	NS	NS	0.167	0.263	NS
C.V.%			9.46			18.77			7.92

	Y	B x Y	S x Y	B x S x Y
S. Em. ±	0.06	0.08	0.13	0.18
C. D. at 5%	0.17	NS	NS	NS
C.V.%				7.99

Note: Figures outside the parenthesis indicate square root transformed value

Table 2: Effect of silicon and boron on number of fruits per panicle at marble stage in mango cv. Sonpari

Number of fruits per panicle at marble stage									
Treatments	**2017-18**			**2018-19**			**Pooled**		
	B_1	**B_2**	**Mean (S)**	**B_1**	**B_2**	**Mean (S)**	**B_1**	**B_2**	**Mean (S)**
S_1	7.62	10.12	8.87	7.15	9.87	8.51	7.38	9.99	8.69
S_2	8.78	8.85	8.82	8.45	8.55	8.50	8.62	8.70	8.66
S_3	10.70	12.23	11.47	9.63	11.65	10.64	10.17	11.94	11.05
S_4	8.50	10.47	9.48	8.42	10.20	9.31	8.46	10.33	9.40
S_5	9.28	12.15	10.72	9.43	11.48	10.46	9.36	11.82	10.59
Mean (B)	8.98	10.76	9.87	8.62	10.35	9.48	8.80	10.56	9.68
	B	S	B x S	B	S	B x S	B	S	B x S
S. Em. ±	0.18	0.29	0.41	0.28	0.45	0.63	0.17	0.27	0.39
C. D. at 5%	0.54	0.85	1.20	0.84	1.32	NS	0.50	0.80	1.15
C.V.%			7.16			11.57			9.77

	Y	B x Y	S x Y	B x S x Y
S. Em. ±	0.16	0.23	0.37	0.52
C. D. at 5%	NS	NS	NS	NS
C.V.%				9.30

Table 3: Effect of silicon and boron on number of fruits per panicle at harvest stage in mango cv. Sonpari

Number of fruits per panicle at harvest stage									
Treatments	**2017-18**			**2018-19**			**Pooled**		
	B1	**B2**	**Mean (S)**	**B1**	**B2**	**Mean (S)**	**B1**	**B2**	**Mean (S)**
S_1	0.98	1.78	1.38	0.88	1.48	1.18	0.93	1.63	1.28
S_2	1.17	1.50	1.33	1.08	1.13	1.11	1.13	1.32	1.22
S_3	2.03	2.42	2.23	1.43	1.77	1.60	1.73	2.09	1.91
S_4	1.15	1.93	1.54	1.03	1.53	1.28	1.09	1.73	1.41
S_5	1.40	2.35	1.88	1.32	1.85	1.58	1.36	2.10	1.73
Mean (B)	1.35	2.00	1.67	1.15	1.55	1.35	1.25	1.78	1.51
	B	S	B x S	B	S	B x S	B	S	B x S
S. Em. ±	0.04	0.07	0.09	0.04	0.06	0.08	0.03	0.05	0.07
C. D. at 5%	0.12	0.20	0.28	0.11	0.17	0.24	0.09	0.14	0.20
C.V.%			9.69			10.59			11.26

	Y	B x Y	S x Y	B x S x Y
S. Em. ±	0.02	0.03	0.06	0.08
C. D. at 5%	0.07	0.10	0.16	NS
C.V.%				8.92

Table 4: Effect of silicon and boron on number of fruits per tree in mango cv. Sonpari.

Number of fruits per tree									
Treatments	**2017-18**			**2018-19**			**Pooled**		
	B1	**B2**	**Mean (S)**	**B1**	**B2**	**Mean (S)**	**B1**	**B2**	**Mean (S)**
S_1	148.33	163.33	155.83	141.67	155.33	148.50	145.00	159.33	152.17
S_2	155.00	165.33	160.17	149.00	157.00	153.00	152.00	161.17	156.58
S_3	169.33	193.00	181.17	178.67	187.00	182.83	174.00	190.00	182.00
S_4	152.00	165.67	158.83	148.33	173.33	160.83	150.17	169.50	159.83
S_5	158.67	182.67	170.67	152.33	185.33	168.83	155.50	184.00	169.75
Mean (B)	156.67	174.00	165.33	154.00	171.60	162.80	155.33	172.80	164.07
	B	S	B x S	B	S	B x S	B	S	B x S
S. Em. ±	3.64	5.75	8.14	4.94	7.81	11.04	4.56	6.82	10.52
C. D. at 5%	10.73	16.97	NS	14.57	23.04	NS	13.71	20.54	NS
C.V.%			8.52			11.75			10.20
						Y	B x Y	S x Y	B x S x Y
S. Em. ±						5.05	6.65	11.30	14.87
C. D. at 5%						NS	NS	NS	NS
C.V.%									7.67

Table-5: Effect of silicon and boron on fruit yield in mango cv. Sonpari									
Fruit yield (kg/tree)									
Treatments	**2017-18**			**2018-19**			**Pooled**		
	B1	**B2**	**Mean (S)**	**B1**	**B2**	**Mean (S)**	**B1**	**B2**	**Mean (S)**
S_1	45.32	55.22	50.27	43.92	50.68	47.30	44.62	52.95	48.78
S_2	48.66	58.20	53.43	47.50	56.86	52.18	48.08	57.53	52.80
S_3	62.98	67.89	65.44	60.71	66.89	63.80	61.85	67.39	64.62
S_4	48.39	61.15	54.77	47.11	62.09	54.60	47.75	61.62	54.69
S_5	50.24	65.55	57.90	54.56	64.90	59.73	52.40	65.23	58.81
Mean (B)	51.12	61.60	56.36	50.76	60.28	55.52	50.94	60.94	55.94
	B	S	B x S	B	S	B x S	B	S	B x S
S. Em. ±	2.02	3.20	4.52	2.00	3.18	4.49	1.92	3.03	4.29
C. D. at 5%	5.96	9.43	NS	5.93	9.37	NS	5.66	8.95	NS
C.V.%			13.89			14.02			18.79

	Y	B x Y	S x Y	B x S x Y
S. Em. ±	0.62	0.87	1.38	1.95
C. D. at 5%	NS	NS	NS	NS
C.V.%				6.05

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