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Interactive Effects of Silicic Acid and NOVEL on Tomato Performance under Protected Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. Authors RPJ and SK designed the study and wrote the manuscript. Authors AKP and NBP carried out the statistical analysis. Author JMM helped in analysis of the study. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The present investigation was carried out in tomato under protected culture to find out the effect of silicic acid (0.0%, 0.1%, 0.2% and 0.3%) and Novel organic liquid nutrient (NOVEL) [0.0%, 1.0%, 1.5% and 2.0%] spray on tomato performance under protected conditions.
Study Design: The study was conducted in a factorial experiment based on randomized complete block design.
Place and Duration of Study: The experiment was conducted under naturally ventilated polyhouse at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat), India between December 2017 and June, 2018.
Methodology: The experiment comprising of 16 treatments with 4 levels each of silicic acid (0.0%, 0.1%, 0.2% and 0.3%) and Novel organic liquid nutrient (NOVEL- a brand product of NAU, Navsari prepared from banana pseudo stem) [0.0 to 1.0 % and 1.5 to 2.0 %] was carried out in tomato cv. Arka Rakshak. The data on plant height (cm) and leaf area (cm^2) was taken from 5 randomly tagged

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plants. Reproductive traits like days to 50% flowering, days to first picking, number of pickings, days to last picking were recorded in plant population accommodated in net plot area (1.5 × 4.5 m^2). Fruit set (%) was worked out by counting number of flowers per truss and their successive fruiting in each tagged plant during cropping span of tomato. Number of fruits and fruit weight at each picking were recorded in each tagged plant. The marketable as well as unmarketable fruits harvested from each net plot were weighed separately at each picking to calculate yield per plant and per unit area. The observation on leaf miner was made at weekly interval by counting total number and damaged leaflets from five randomly tagged plants.

Results: The analysis of data revealed significance of individual effect majorly of silicic acid on most of the traits under study. The effect of NOVEL was limited to few characters while interaction effect was found to be non significant for all the traits except leaf miner incidence. The results on plant height, days to 50 % flowering, days to first picking, and average fruit weight were found to be non-significant. Silicon as silicic acid (0.3%) recorded higher leaf area at final harvest (593.35 cm^2), fruit set percentage (59.86), number of fruits per plant (49.68), days to last picking (186.16 days) and correspondingly higher marketable yield per plant (3.76 kg), total yield per plant (3.99 kg), marketable yield per m^2 (10.82 kg) and total yield per m^2 (11.48 kg). Different levels of NOVEL were found to influence number of pickings significantly and 1.5% NOVEL showed maximum number of pickings (29.92) during the cropping span of tomato. Leaf miner incidence was governed by individual as well as interaction effect of silicic aid and NOVEL with minimum incidence if 2.79% in plants sprayed with combination of silicic acid and NOVEL (0.1% + 1.0%)

Conclusion: Silicon as 0.3% silicic acid was turned out to be the potential treatment to achieve maximum leaf area, fruit set, number of fruits per plant, yield and enhanced cropping span. Silicic acid and NOVEL (0.1% + 1.0%) interactively have ability to strengthen the plant defence mechanism to resist leaf miner infestation.

Keywords: Greenhouse tomato; silicon; organics; horticultural traits; leaf miner.

1. INTRODUCTION

Protected cultivation being the most efficient mean to overcome climatic variations, has potential of fulfilling the requirements of growers as it can increase the yield manifolds and at the same time improve quality of produce significantly as per the demand of market [1]. In modern agriculture, greenhouse technology can be utilized for the management of environmental parameters such as temperature, relative humidity, light intensity, light duration, CO_2 level, irrigation, nutrient supply and uptake, spacing, growing medium and root development [2].

Tomato (*Solanum lycopersicum* L.), a member of 'Solanaceae' family, is one of the most important greenhouse vegetable crops worldwide. It is an indispensable source of carotenoids providing an estimated 80% of daily intake of lycopene and folate, ascorbic acid, flavonoids, α-tocopherol [3, 4].

Nutrients plays an essential role in growth and development of a crop, so judicious management of all agricultural inputs in greenhouse tomato production system is vital to achieve full production potential. Foliar application of nutrients fulfils the nutrient demand of growing plants rapidly that ameliorates nutrient deficiencies appropriately. Although, tomato is typically a Si-excluder plant species [5] but severe reduction on tomato growth and yield have been observed in the absence of Si under greenhouse [6]. Silicon has structural and metabolic functions to play in the plant physiology and also has ability to affect plant growth, quality, stimulation of photosynthesis, reduction of transpiration and generating numerous benefits which may result in increase of productivity in several plant species [7, 8, 9, 10]. Plant assimilates silicon in the form of silicic acid which travels to active growing points complexing with organic compounds in cell walls and make them stronger. Silicon promotes upright growth, prevents lodging, promotes favourable exposure of leaves to light, provides resistance to bacterial and fungal diseases and decreases the impact of some abiotic stresses like temperatures, salinity, heavy metal and aluminium toxicity [11].

Use of organic manures alone can't fulfil the crop nutrients requirement [12]. However, organic manures, when applied with chemical fertilizers gives better yield than individual ones [13]. Novel Organic Liquid Nutrient (NOVEL), a brand product of NAU prepared from banana pseudo

stem contains nutrients like N, P, K, Zn, Fe, B *etc.* and growth promoting substances namely cytokinin, GA_3 *etc.* [14], which can be useful in different stages of plant growth such as vegetative development, flowering, fruit setting, fruit development *etc.* Therefore, present investigation was planned to elucidate the effect of silicon as silicic acid and nutrient spray in tomato under protected environment.

2. MATERIALS AND METHODS

2.1 About the Location

The experiment was conducted under naturally ventilated polyhouse (multispan saw tooth type) at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat), positioned at 20°57' N and 72°54' E with an altitude of 11.89 AMSL. The mean temperature inside NVPH was 28.05°C during the growing period of tomato, while the maximum and minimum temperatures were 35.18 and 20.93°C, respectively with mean relative humidity of 67.58 %. The EC and pH of water used during the period of investigation were worked out to be 0.2 dS m^{-1} EC (Conductometric Method) and 6.4 (Potentiometric Method), respectively [15].

2.2 Experimental Material and Layout

The experiment comprising of 16 treatments with 4 levels each of silicic acid (S1: 0.0 %, S2: 0.1 %, S3: 0.2 % and S4: 0.3 %) and Novel organic liquid nutrient (NOVEL) [N1: 0.0, N2: 1.0 %, N3: 1.5 and N4: 2.0 %] were carried out in tomato cv. Arka Rakshak during *Rabi* 2017-18 and laid out in a factorial experiment based on randomized complete block design with three replications. Six sprays of each treatment were made during cropping span of tomato, first being at 20 days after planting and remaining applications were done at and interval of 20 days. Tomato plants were grown on raised beds having dimensions of 100 cm × 40 cm × 50 (width, height and distance between two beds) with inter and intra-row spacing of 60 cm and 45 cm, respectively occupying gross area of 3.0 × 5.4 m^2 (48 plants) and net area of 1.5 × 4.5 m^2 (20 plants) per treatment.

The common application of N: P: K as per the recommendation (250:125:125 kg ha^{-1}) was administered to each treatment through MIS using prescribed fertigation schedule. Grade-V micronutrient (50 kg ha^{-1}) was also applied to each treatment at the time of transplanting [16].

2.3 Data Recording

The data on growth characteristics namely plant height (cm) and leaf area (cm^2) was taken from five randomly tagged plants from each plot. Plant height was recorded with the help of meter tape at final harvest, while non-destructive method of leaf area determination was followed having 98% precision (0.98 R^2) [17]

$$\text{Leaf Area} = \{0.347*(\text{Length}*\text{Width})\} - 10.7$$

Length and breadth of 3 leaves from upper, middle and lower portion of each randomly tagged plant were measured at final harvest and average values were used to fit into above mentioned equation for leaf area determination.

Phenological characteristics like days to 50% flowering, days to first picking, number of pickings, days to last picking were recorded in plant population accommodated in net plot area. Fruit set (%) was calculated out by counting number of flowers per truss and their successive fruiting in each tagged plant during cropping span of tomato. Number of fruits and fruit weight at each picking were recorded in each tagged plant, and average number and weight were recorded out at the end of cropping season. The marketable as well as unmarketable fruits harvested from each net plot were weighed separately at each picking to work out yield per plant and per unit area. The observation on leaf miner was made at weekly interval by counting total number and damaged leaflets from five randomly tagged plants of each plot and expressed as per cent damage [18].

2.4 Statistical Analysis

The standard method of analysis of variance technique appropriate to randomized block design was used by employing 'F' test at 5% level of significance and critical difference ($CD_{0.05}$) was also worked out to compare the treatment means using WASP 2.0 (Web Agri Stat Package) [19]. Different letters in the figures and the tables represent significant variations according to CD ($P \leq 0.05$).

3. RESULTS AND DISCUSSION

3.1 Effect on Growth Traits

Fig. 1 shows the results of foliar application of different levels of silicic acid and NOVEL on vegetative and reproductive parameters of tomato under protected environment. Plant height of tomato remained unaffected by different

levels of silicic acid as well as Novel organic liquid nutrient. However, silicic acid (0.3%) recorded maximum plant height of 195.58 cm at final harvest, while 2.0% spray among different levels of NOVEL showed maximum plant height (194.87 cm). Similarly, differences due to different levels of NOVEL were observed to non-significant for leaf area. However, leaf area was significantly influenced by different levels of silicic acid and it was observed to be maximum (593.35 cm^2) at 0.3% level of silicic acid with statistical parity with 0.2 and 0.1 % levels of silicic acid. Such an increase in leaf area may be attributed to the role of silicon in improving cell wall thickness that helps to produce bigger stalks and stems, and influence leaf area significantly in crops like tomato [20] and cucumber [21].

3.2 Effect on Reproductive Traits

The results showed non-significant effect of different levels of silicic acid, NOVEL as well as of interaction between silicic acid and NOVEL on days to 50% flowering and days to first picking (Fig. 2). As crop was exposed to different treatments at 20 days after planting in the present study, this couldn't have made sufficient physiological changes in tomato to trigger earliness in flowering. The results are not agreement with the findings of earlier workers [22], who actually adopted more number of sprays in tomato prior to 50% flowering in comparison to present investigation.

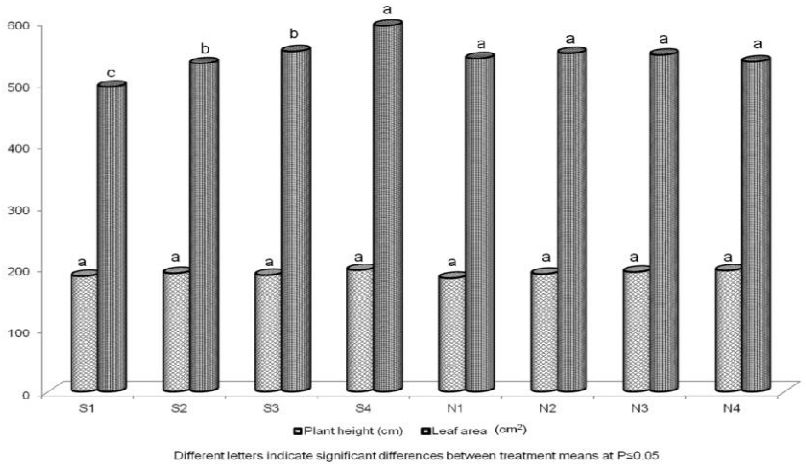

Fig. 1. Effect of silicic acid and Novel organic liquid nutrient on plant height and leaf area of tomato under protected environment

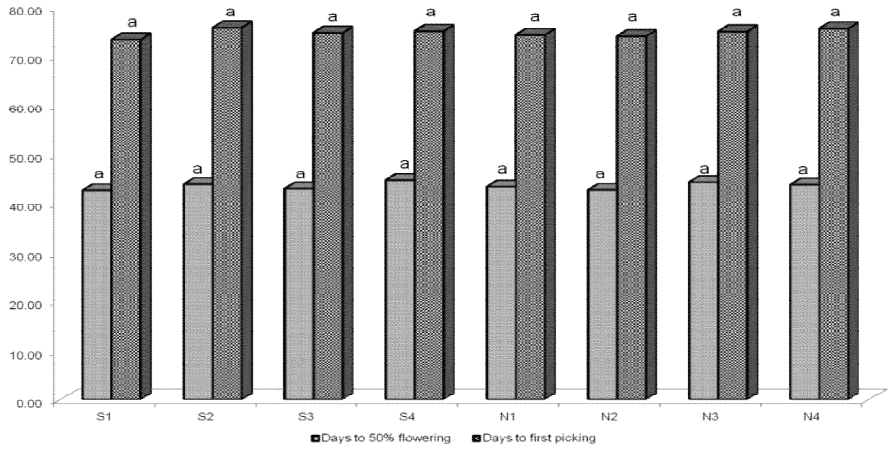

Fig. 2. Effect of silicic acid and Novel organic liquid nutrient on days to 50% flowering and picking of tomato under protected environment

The fruit set percentage was significantly influenced by different levels of silicic acid but remained unaffected by different levels of NOVEL and treatment interaction between silicic acid and NOVEL (Fig. 3). Silicic acid at 0.3% showed maximum fruit set (59.86%), which was at par with 0.2 as well as 0.1% silicic acid. Silicon plays an important role to enhance photosynthetic activity, production and accumulation of carbohydrates, and exert favourable effect on leaf area and retention of flowers, which increased fruit set percentage [23, 24, 25]. Silicic acid at 0.3% also extended the cropping span of tomato significantly compared to other levels of silicic acid by taking maximum number of days to last picking (186.16) [Fig. 3]. Silicic acid helps to improve accumulation of photosynthates leading to enhanced duration of tomato and cucumber [21, 23, 26]. In case of NOVEL levels, maximum number of days taken to last picking was displayed by of NOVEL at 1.5%, which was at par with 2.0% and 1.0% levels of NOVEL. Application of NOVEL provided a stimulus in the plant system, which in turn increased the production of growth regulators in the cell system leading to better growth and development [22].

3.3 Effect on Yield Traits

The results pertaining to effect of silicic acid and NOVEL on different yield parameters studied in the present investigation are presented in Figs. 3 & 4, which clearly reveal the significance of main effect of silicic acid on majority of these traits. Silicic acid (0.3%) recorded significantly higher number of fruits per plant (49.68) with at par performance in 0.1% and 0.2% silicic acid. Such a trend for fruit number could be corresponded to enhanced photosynthetic activity and retention of productive flowers as observed in tomato and chilli by earlier workers [23, 25, 27, 28]. Correspondingly, 0.3% silicic acid also recorded maximum marketable yield per plant (3.76 kg), total yield per plant (3.99 kg), marketable yield per m^2 (10.82 kg) and total yield per m^2 (11.48 kg), which was at par with 0.2% silicic acid. Increased yield due to silicic acid application may be qualified due to improved photosynthetic activity of plants, resulting in increased production and accumulation of carbohydrates [23]. The advantageous effect on leaf area and fruit setting have also contributed towards higher number of fruits per plant, which is directly correlated to marketable yield per plant. Earlier research carried out in tomato, chilli and cucumber also substantiate the results of present investigation [21, 23, 26, 29]. The results on total number of pickings were observed to be non-significant due to different levels of silicic acid as well as combination between silicic acid and NOVEL. However, different levels of NOVEL showed significant differences for the trait and 1.5% NOVEL was observed to record maximum number of pickings (29.92) with at par performance in plants sprayed with NOVEL at 1.0%. As NOVEL contain many nutrients like nitrogen, phosphorus, potassium, zinc, iron, boron *etc*., which might have increased cropping span owing to the availability of these nutrients via 6 spray schedules followed in the present study. However, data shows non-significant effect of different levels of silicic acid, NOVEL as well as combinations between silicic acid and NOVEL on average fruit weight. Earlier researcher also opined that true fruit characteristic of a variety remains unchanged due to the application of silicon [26]. Different levels of NOVEL and treatment combinations between silicic acid and NOVEL had non-significant effect on all the yield parameters. Similar trend in the results was also obtained while using organic growth promoters in tomato [30].

3.4 Effect on Leaf Miner Incidence

Table 1 shows significant results due to individual as well as interaction effect of different levels of silicic acid and NOVEL on leaf miner incidence in tomato under polyhouse conditions. Tomato plants sprayed with silicic acid (0.1%) exhibited significantly minimum leaf miner infestation (3.42 %). The incidence of leaf miner was observed to be significantly minimum (3.20%) in plants supplied with 1.5% NOVEL. Moreover, combination of 0.1% silicic acid and 1.0% NOVEL spray was very effect to record significantly minimum incidence of leaf miner (2.08%) under protected environment. This might be due to mechanical strength provided by silicon to plant tissues, which increased their tolerance to several biotic factors and the supplements provided by NOVEL to crop also have ability to strengthen the plant mechanism against such biotic factors [11]. Silicon-based treatments when applied to the leaves, the midgut epithelium showed detachment of the basal membrane, which can characterize the possible effect of this toxic element to larvae of *T. absoluta* [31].

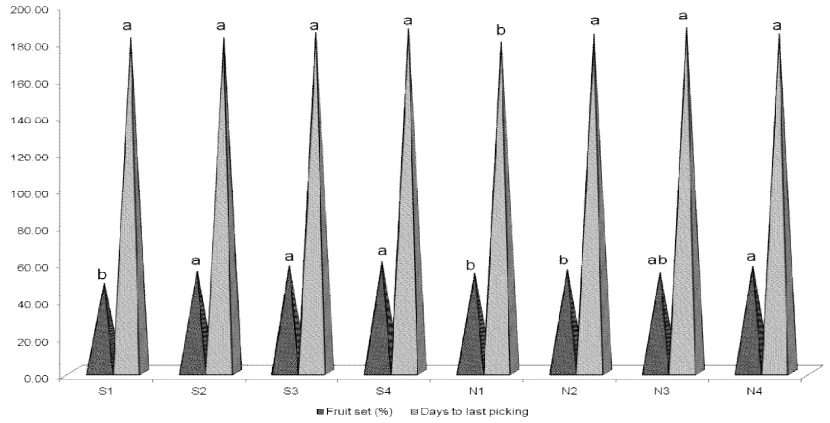

Fig. 3. Effect of silicic acid and Novel organic liquid nutrient on fruit set and days to last picking of tomato under protected environment

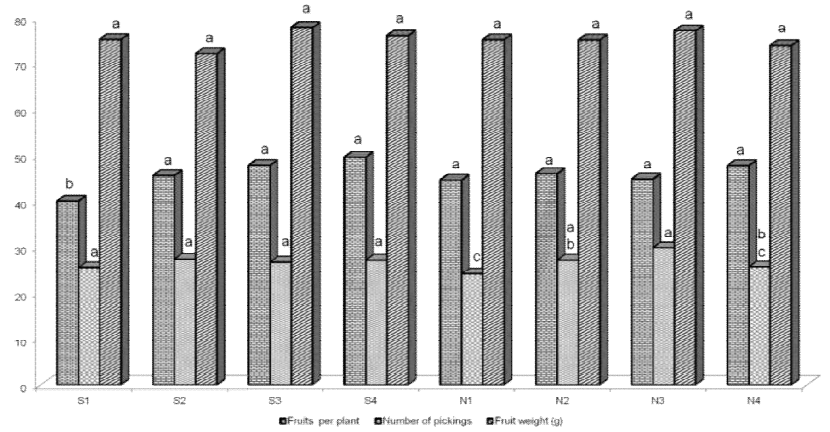

Fig. 4. Effect of silicic acid and Novel organic liquid nutrient on fruit per plant, number of pickings and fruit weight of tomato under protected environment

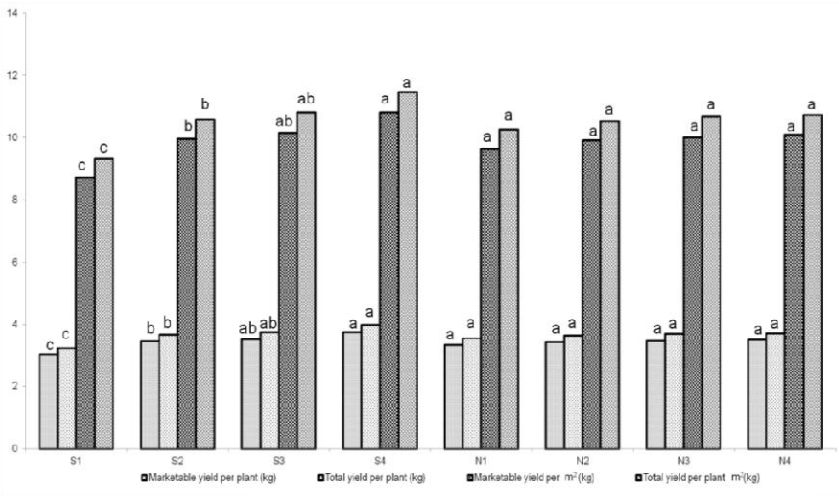

Fig. 5. Effect of silicic acid and Novel organic liquid nutrient on yield of tomato under protected environment

Table 1. Effect of silicic acid and Novel organic liquid nutrient on leaf miner incidence in tomato under protected environment

Treatment levels	Leaf miner incidence (%)*				
	NOVEL (0.0%)	NOVEL (1.0%)	NOVEL (1.5%)	NOVEL (2.0%)	Mean
Silicic acid (0.0 %)	5.38^{b}(13.39)	3.71^{0}(10.98)	3.62^{b}(10.85)	5.35^{b}(13.35)	4.52^{b}(12.14)
Silicic acid (0.1 %)	5.81^{cd}(13.92)	2.08^{a}(8.22)	3.30^{ab}(10.45)	2.48^{a}(8.97)	3.42^{a}(10.39)
Silicic acid (0.2 %)	4.59^{bc}(12.08)	5.31^{b}(13.28)	2.79^{a}(9.59)	5.46^{cd}(13.51)	4.54^{b}(12.11)
Silicic acid (0.3 %)	5.11^{b}(13.04)	6.53^{d}(14.80)	3.08^{a}(10.05)	4.65^{b}(12.33)	4.84^{b}(12.56)
Mean	5.22^{c}(13.11)	4.41^{b}(11.82)	3.20^{a}(10.24)	4.49b^{c}(12.04)	

*(*Values inside the parentheses are arc sine transformed)*

4. CONCLUSION

It can be concluded that individual effect of silicic acid affected most of the parameters under investigation and silicon as 0.3% silicic acid was turned out to be the potential treatment to achieve maximum leaf area, fruit set, number of fruits per plant, yield and enhanced cropping span. Silicic acid and NOVEL (0.1% + 1.0%) interactively have ability to strengthen the plant mechanism to resist leaf miner infestation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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