Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(2): 1552-1558
Received: 13-01-2019
Accepted: 16-02-2019

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Effect of foliar application of silicon on growth and development of okra fruit

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Abstract
Okra (*Abelmoschus esculentus* L.) (2n=130) is known in many English-speaking countries as lady's fingers or gumbo and it is a flowering plant in the *Malvaceae* family. Silicon is known as a multifunctional element that significantly increases plant growth, productivity, plant tolerance and enhances resistance against insect and pests. The aim of this investigation was to improve growth characters in okra (*Abelmoschus esculentus* L.) by foliar application of silicic acid. A field experiment was conducted at main vegetable research station farm, Anand, to investigate whether foliar application of silicic acid could ameliorate the okra growth. Four okra cultivars GAO 5, Pusa sawani, AOL 1022 and Arka anamika were exposed to four treatments of silicic acid with different time intervals. The fruit length, weight, girth, volume, no of fruits per plant, plant height and 100 seed weight were recorded higher in GAO 5 and foliar spray of silicic acid at 15 DAG i.e. treatment (T_2). Disease incidence was found to be reduced at early stage foliar spray of silicic acid treatment (T_2) compared to all other treatments. Among the different crop growth stages, at early vegetative stage i.e. 15 DAG had greater beneficial effect on okra fruit, followed by fruit received from late vegetative (T_3=30 DAG) and flowering stage (T_4=45 DAG0. Applications of silicic acid enhanced the overall growth of okra varieties.

Keywords: Foliar application, silicon, growth, development, okra fruit

Introduction
Okra (*Abelmoschus esculentus* L. Moench) is one of the most important and widely grown crops found throughout the tropical and sub-tropical regions of the world. It is an annual, erect growing, high yielding crop with numerous cultivars varying in plant height, degree of branching and pigmentation of the various parts, period of maturity, and pod shape and size. It is mainly grown for its tender green pods and leaves, which are cooked and commonly consumed as boiled vegetables [1]. The total commercial production of okra in the world was estimated at 4.8 million tons, with India and Nigeria being the predominant producers [2]. Other minor producers include Pakistan, Ghana, Egypt, Ethiopia, Iran, Iraq, Turkey, Brazil, Guyana, Japan and USA.

Silicon (Si) is the second most abundant element in the earth's crust and plays a number of important roles in the mineral nutrition of plants. In the past 20 years, the scientific documentation on the benefits of Si to crops has helped establish Si fertilization as an agronomic practice in many agricultural lands worldwide. Si increases crop productivity and improves technological quality, while the lack of this element can reduce the plants' biological ability to withstand adverse environmental conditions (Rafi; Epstein; Falk, 1997) [9]. Silicon plays an important role in strengthening the cell walls of the plants and enhances resistance to both pests and diseases in wheat, rice, maize and vegetable crops. Various scientists (Matichenkov and Calvert, 2000) [8] have reported the benefits of Si in plants, such as increased growth, rigidity of the mature leaves and yields. However, very little information has been consolidated on the use of Si specifically for US agriculture.

Materials and Methods
The field experiment was conducted on the main vegetable research station farm at Anand agricultural university, Anand during Kharif 2015-16. The four different okra varieties collected from Main Vegetable Research Station; Anand Agricultural University; Anand. Four okra verities were used namely GAO 5, Pusa sawani, AOL 1022 and Arka anamiak. They were evaluated in a Factorial Randomized Block Design (FRBD) with three replications.

Recommended plant protection measures and cultivation practices were followed during the course of experimentation to raise a good crop. All the observations with respect to morphological changes of okra varieties with different treatments were recorded after 60 DAG. Data were analyzed by using statistical software Statistix 8.1.

Silicon levels and application
During this study 0.1% silicic acid level with different time intervals were used. Silicic acid was mixed in distillated water and was applied to plants exogenously as a foliar spray at 15 DAG (T2), 30 DAG (T3) and 45 DAG (T4). The plants without foliar spray of silicic acid denoted as control (T1).

Morphological Characters
Fruit length (cm)
Randomly 5 fruits were selected from each selected plant and length was measured by using vernire calipers and expressed in centimeters.

Fruit weight (g)
Randomly 5 fruits were selected from each selected plant and weighed on weighing balance and fruit weight was expressed in grams.

Fruit girth (cm)
Randomly 5 fruits were selected from each selected plant and fruit girth was measured and expressed in centimeters.

Fruit volume
The fruit volume of 5 randomly selected fruits were measured after the harvest. Volumes of fruits were measured by the water displacement method. The fruit was placed in measuring glass cylinder filled with water and the replaced water was measured for each treatment and data were recorded as volume of the fruit in cubic centimeter.

No. of fruits per plant
Total yield per plant from each selected plant as well as per plot were recorded and converted into fruit yield quintal per hectare.

Plant height (cm)
Plant height of 5 randomly selected plants of each variety was measured from the base of the stem to the apex of the central leaf at the time of harvest and average was worked out and expressed in centimeters.

100 seed weight (g)
The seeds were harvested and dried under a temperature of 35–40 °C until the seed weight was stable. All the dried seed lots were weighed for the 100-seed weight (g) value.

% Disease incidence
Weekly survey of disease was carried out from July to September during 2015-16. The percent disease incidence was calculated by following formula:

$$\% \text{ Disease incidence } = \frac{\text{No of infected plants}}{\text{Total number of plants}} \text{ x } 100$$

Results and Discussion
Fruit length (cm)
The fruit length from different treatments of silicic acid imposed to okra varieties were tested and data are presented in figure 1. Significantly higher fruit length was observed for variety GAO 5 (15.26 cm). The fruit length of the okra varieties obtained from various treatments resulted into significant differences. Maximum and minimum fruit length was recorded for treatment T_2 (17.52 cm) and T_1 (10.15 cm), respectively. Thus, the treatment T_2 i.e foliar application of silicic acid gave superior fruit length as compared to all other treatments. The various researchers (Kabir and Pillu, 2011, Kasrawi *et al.*, 2007, Weerasinghe *et al.*, 2010) [6, 7, 14] have found that fruit length of okra varied between 9 to 23 cm.

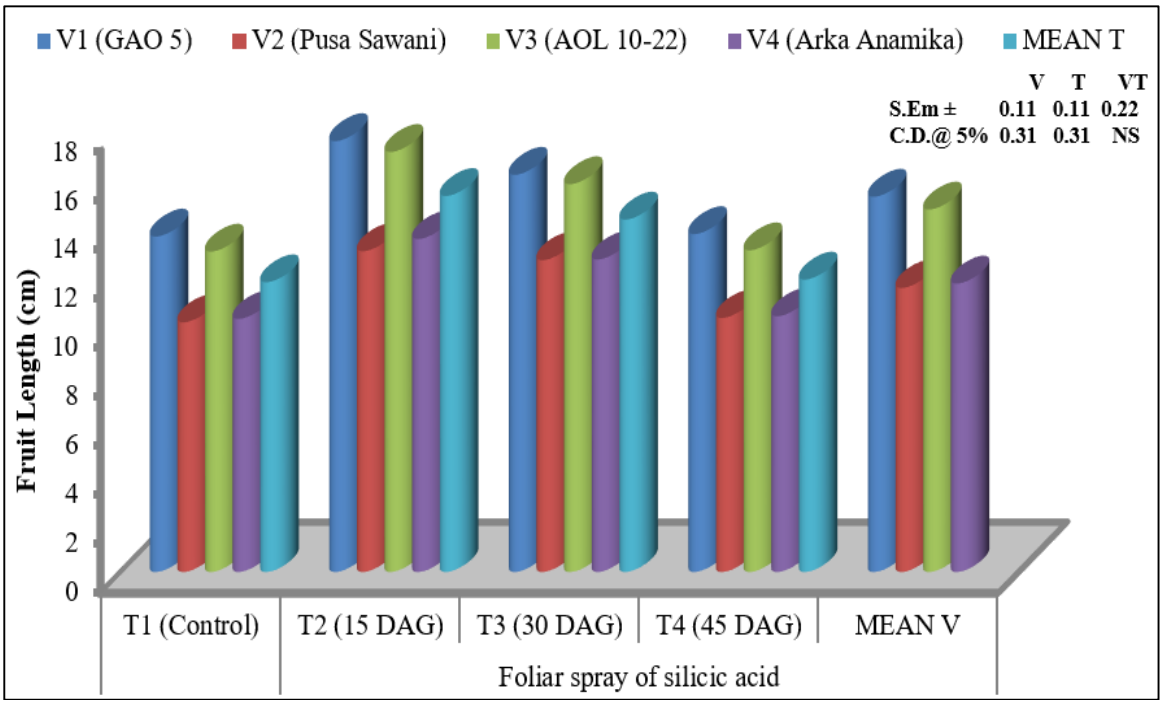

Fig 1: Effect of silicic acid on fruit length (cm) of okra

Fruit weight (g)
Maximum mean value for fruit weight (Figure 2) was recorded in variety GAO 5 (14.60 g). Significantly the highest fruit weight was recorded for T_2 as compared to other treatments. Hence, early stage foliar application of silicic acid i.e treatment T_2 gave better fruit weight as compared to all other treatments. Salimath *et al.*, (2011) [10] reported that the fruit weight of okra was ranged between 10.50 - 25.51 gm during their study on genetic variability.

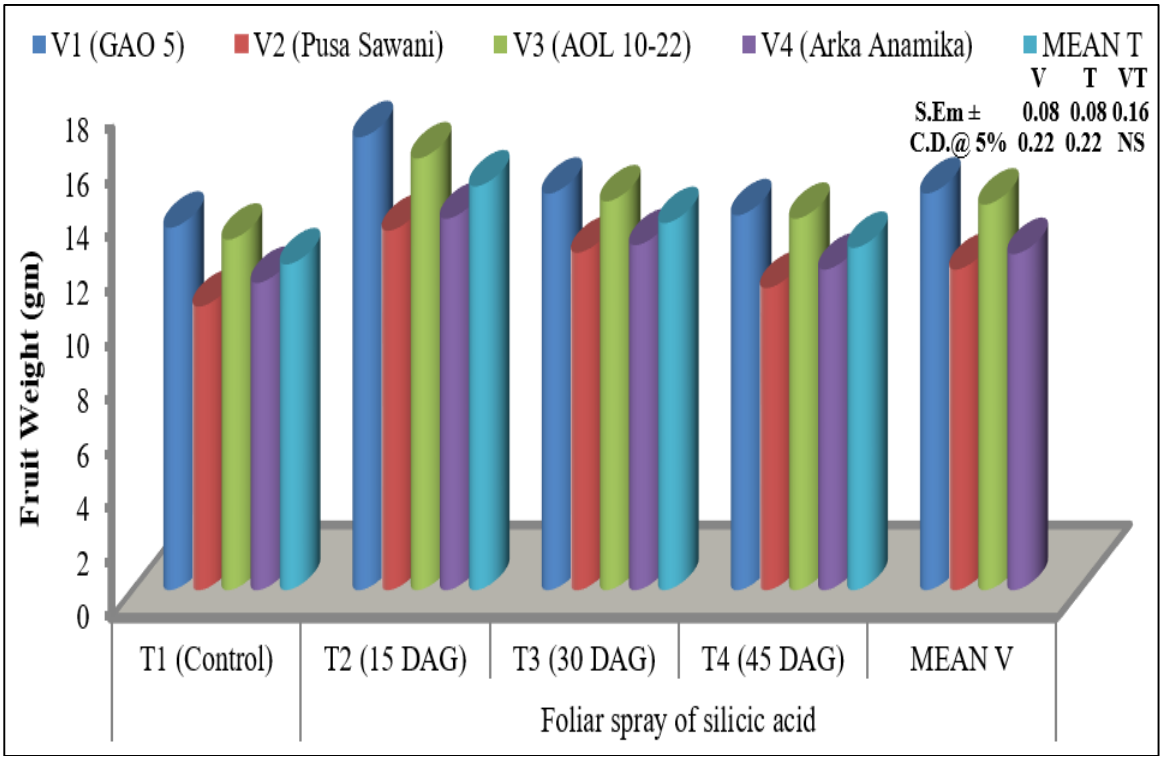

Fig 2: Effect of silicic acid on fruit weight (gm) of okra

Fruit girth (cm)

The fruit girth (Figure 3) was recorded significantly differed with each other. The fruit girth of the okra varieties obtained from various treatments resulted into significant differences. Treatment T_2 registered with higher fruit girth compared to all other treatments. Consequently, the treatment T_2 gave higher shoot length compared to all other treatment. Basar *et al.*, (2011) [1] recorded the highest fruit girth (2.13 cm) in NPK 60, 40, 40 treatments during the study on effect of fertilizer on growth parameters of okra plant.

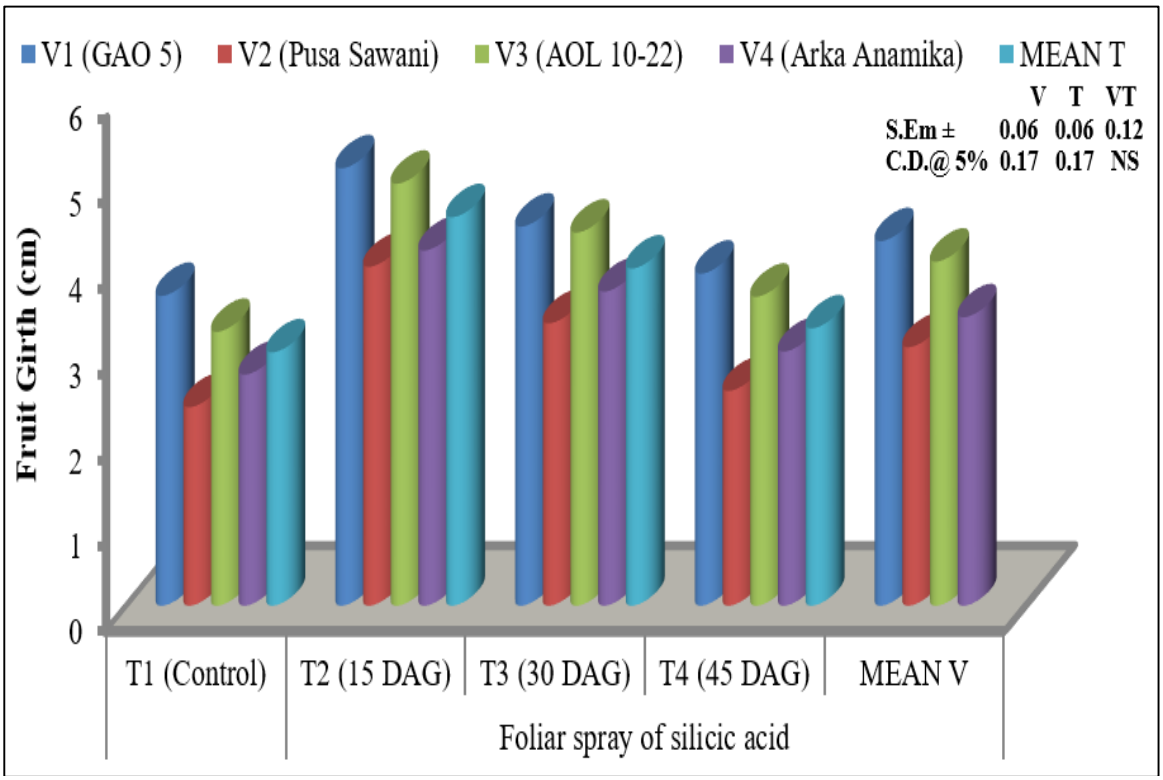

Fig 3: Effect of silicic acid on fruit girth (cm) of okra

Fruit volume (cm3)

Among the okra varieties, significantly maximum fruit volume (Figure 4) was recorded in GAO 5 (12.16 cm3). Treatment T_2 i.e. foliar effect of silicic acid at 15 DAG had significantly highest fruit volume. Thus, the treatment T_2 gave superior fruit volume as compared to all other treatment. Ikrang, (2014) [5] observed that average value of volumes of the three fruits of okra was 13.28 cm3 during the study of physical properties of some tropical fruit.

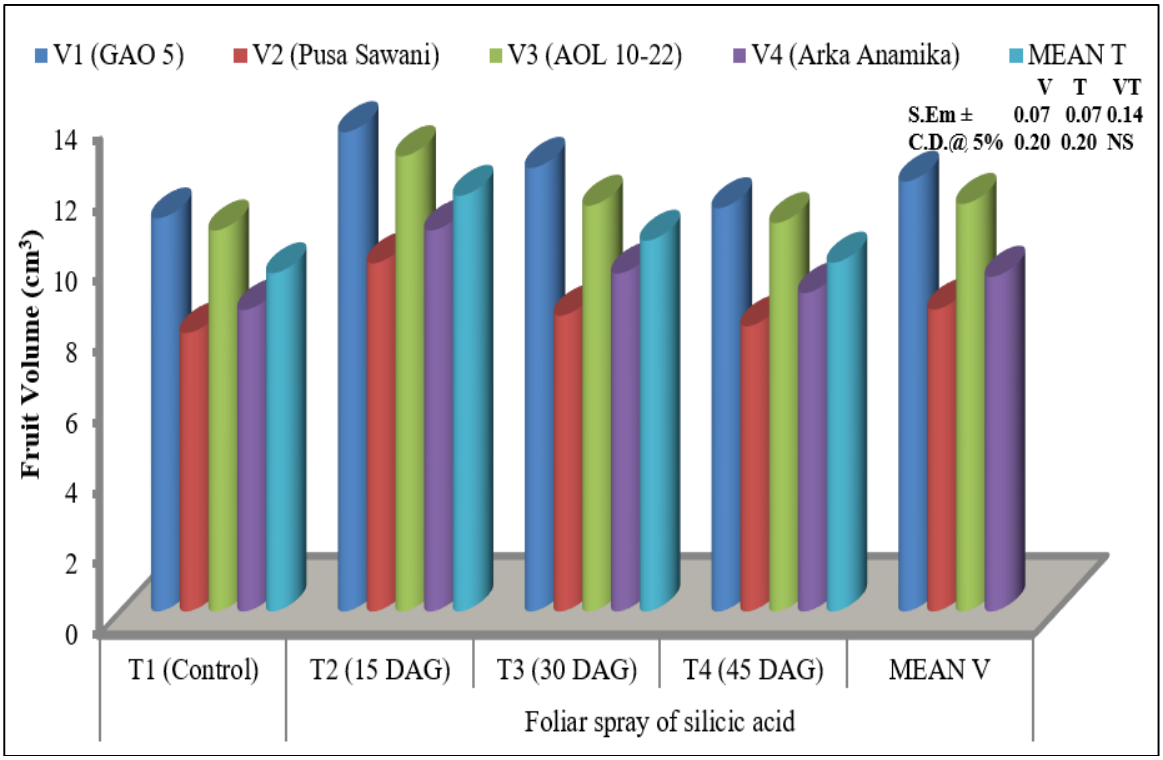

Fig 4: Effect of silicic acid on fruit volume (cm^3) of okra

Number of fruit per plant

The number of fruit per plant from different treatments of silicic acid imposed to okra varieties were tested and data are depicted in figure 5. Significantly the highest number of fruit per plant was recorded in GAO 5 (11). Treatment T_2 i.e. foliar effect of silicic acid at 15 DAG had recorded with significantly maximum number of fruit per plant. Tapankumar and Tripathi, (2009) [13] studied performance of okra hybrids under reduced level of chemical fertilizers and they reported the maximum and the minimum fruit yield with varieties NOH 15 (107.98 q/ha) and Panchali (74.30 q/ha), respectively.

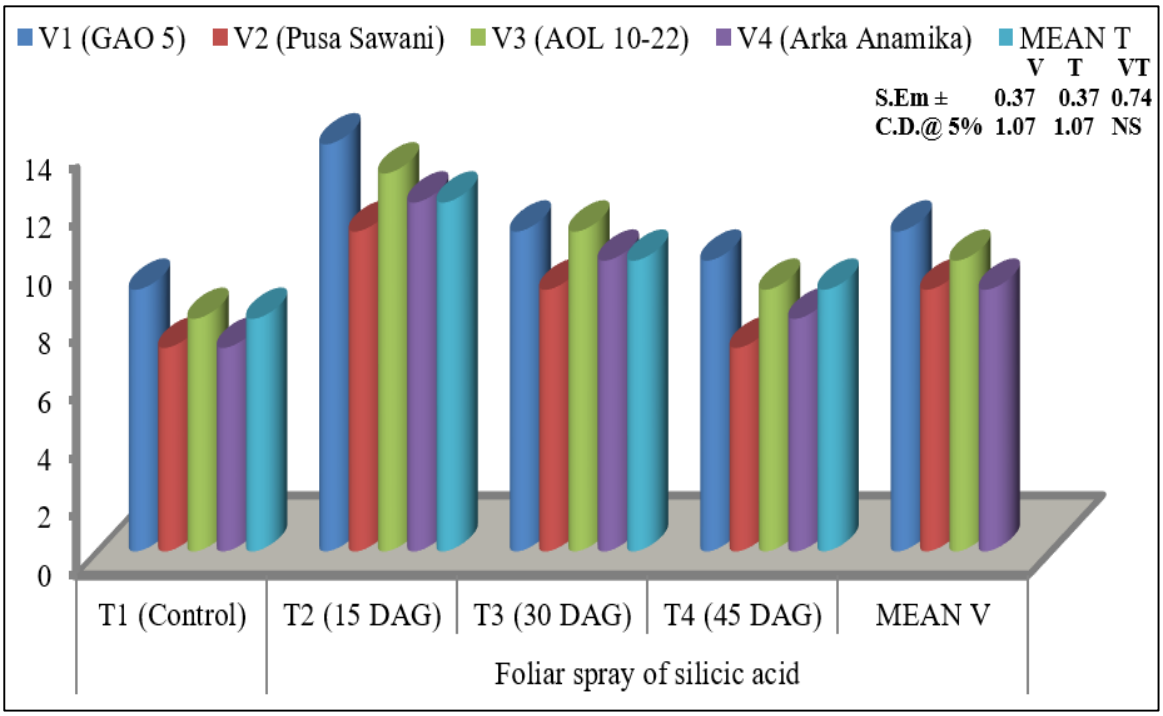

Fig 5: Effect of silicic acid on no. of fruits per plant of okra

Plant height

Variety GAO 5 (108.57 cm) contain significantly higher plant height (Figure 6). The significantly higher plant height was found with treatment T_2. Thus, the treatment T_2 gave superior plant height compared to all other treatment. Talib *et al.*, (2012) [12] studied role of different physico-chemical characters of nine cultivars of okra plant among this the highest plant height was observed for Diksha (132.7cm), while the lowest plant height was with Super star (101 cm). Dhruve *et al.*, (2011) [3] examined the bioefficacy of silixol on okra fruit and recorded that the plant height was improved by foliar application of silixol as compared to control.

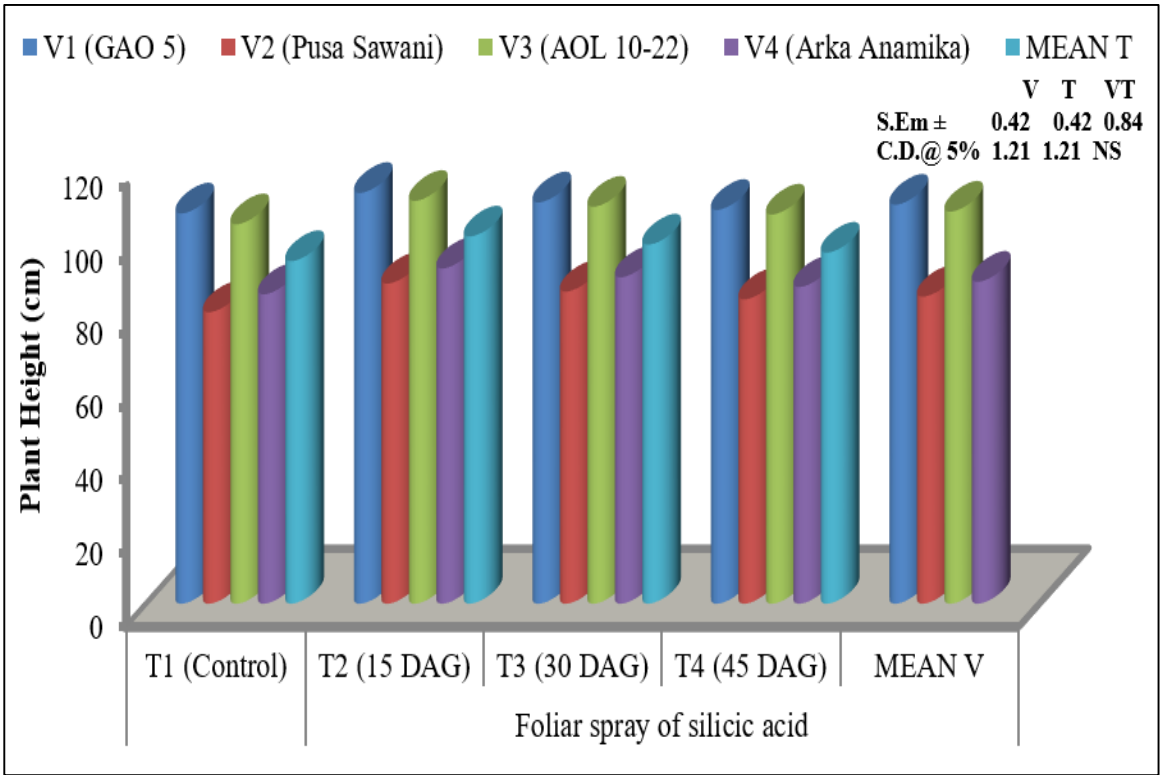

Fig 6: Effect of silicic acid on plant height (cm) of okra

100 seed weight (g)

The effect of silicic acid on 100 seed weight was recorded in figure 7. Maximum mean value for 100 seed weight was recorded in variety GAO 5 (7.99 g). Among the treatments, significantly higher 100 seed weight was recorded for T_2. Results indicated that, the early vegetative stage foliar effect of silicic acid (T_2) was found better as compared to other treatments.

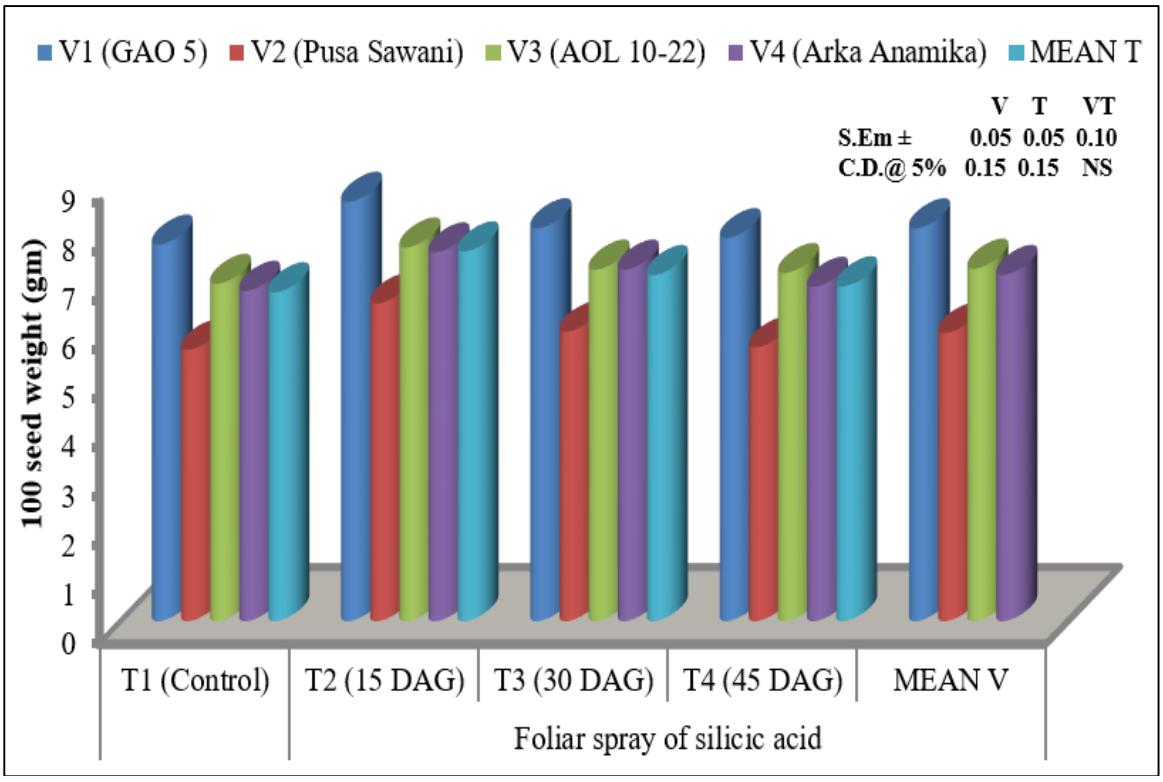

Fig 7: Effect of silicic acid on 100 seed weight (gm) of okra

Disease incidence (%)

The disease incidence (%) from different treatments of silicic acid imposed to okra varieties were tested and data are presented in figure 8. Significantly higher disease incidence was recorded in Pusa sawani (36.11%). The disease incidence of the okra varieties obtained from various treatments also resulted into significant differences. Treatment T_1 (35.07%) was observed with the highest disease incidence as compared to all other treatments. So, the treatment T_1 i.e. control gave maximum disease incidence compared to all other treatments.

The interaction effect between varieties and treatments (VXT) were found to be significant. The interaction effect was found significantly higher in V_2T_1 (52.78%). However, the lower interaction effect was found in V_1T_2 (11.11%). Sheikh *et al.*, (2013) [11] studied effect of bhendi yellow vein mosaic virus on yield components of okra plants. There was significant variation in the above and below ground components between diseased and healthy plants. BYVMV was identified in 86% of all affected samples by a locally produced BYVMV. Disease incidence also varied in different growing seasons. The reduction in yield components incurred by virus infection emphasizes its damaging potential on currently grown okra cultivars in western India.

The interaction effect between varieties and treatments (VXT) were found to be non-significant for all the morphological characters accepts disease incidence.

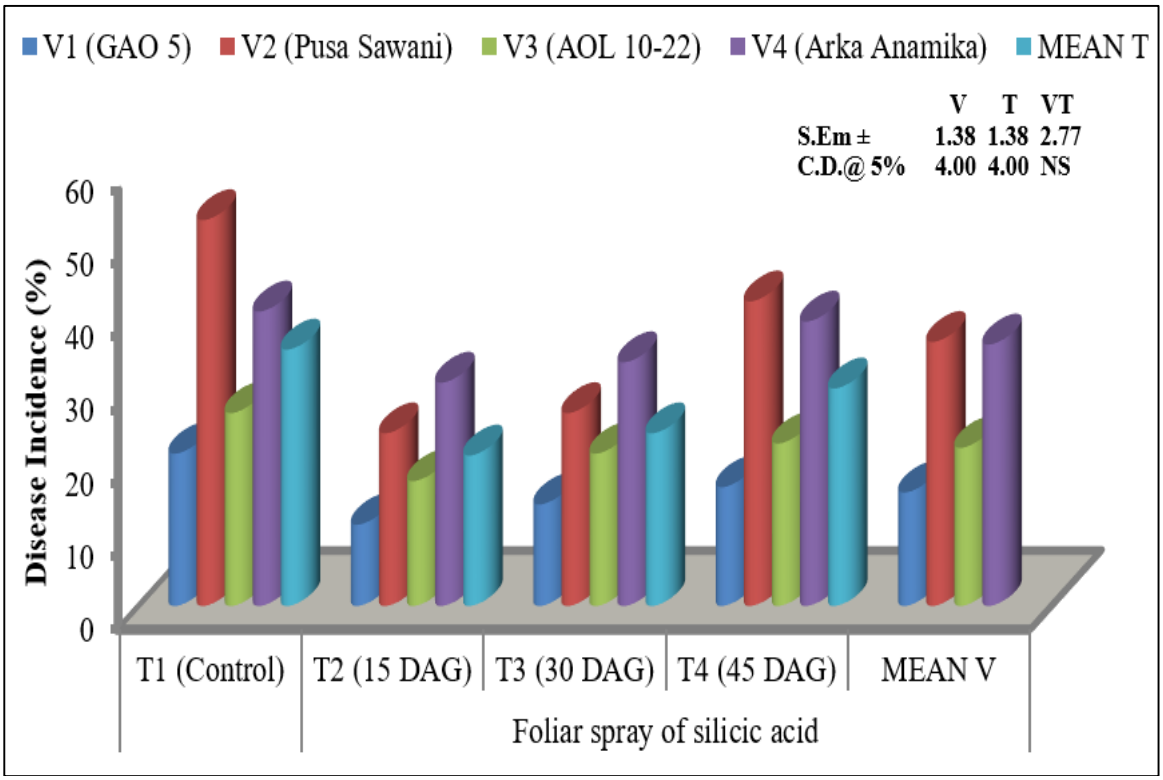

Fig 8: Effect of silicic acid on disease incidence (%) of okra

Conclusion

Morphological characters like fruit length, fruit weight, fruit girth, fruit volume, no of fruits per plant, plant height and 100 seed weight were recorded maximum and minimum in GAO 5 and PusaSawani, respectively. All above morphological characters were recorded higher with treatment T_2. Among all okra varieties and different treatments, significantly higher disease incidence was recorded in PusaSawani with treatment T_1.Thus, early stage foliar application of silicic acid reduced disease and improve growth of okra varieties.

Among the different crop growth stages, at early vegetative stage i.e. 15 DAG had greater beneficial effect on okra fruit, followed by fruit received from late vegetative and flowering stage. The foliar application of silicic acid in general improved the fruit superiority.

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