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Growth Response of Tomato (*Solanum Lycopersicum*) to Seaweed Liquid Fertilizer (SLF) Derived from *Sargassum tenerrimum*

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ABSTRACT

Pakistan cultivates a wide variety of crops across its regions and also has a coastal strip rich in seaweed vegetation. Tomato is one of the most widely consumed crops in Pakistan, used in many ways. Sindh and Balochistan are the leading provinces with the highest tomato yields. Since seaweeds enhance overall crop quality and yield, this study examines the effects of SLF derived from brown seaweed *Sargassum tenerrimum* collected from the Karachi coast on tomato plants. The SLF was tested at three different concentrations, 1%, 2%, and 3%, as a foliar spray. The results indicate that 3% SLF concentration can be used to increase tomato yield, as it not only improved tomato yield but also significantly increased shoot length, plant height, number of leaves, and leaf area.

Keywords: SLF, Tomato plant, *S. tenerrimum*, Physical parameters, Growth stimulants

1. INTRODUCTION

Seaweeds occur naturally all over the world, with a number of species cultivated in many sea-facing countries, including Pakistan (Cabrita, *et al*., 2016; Shahzad, 2023). Several studies suggest that marine seaweeds possess growth stimulants that can not only increase the yield and quality of crops, but also have a lower negative impact on the environment (Houssien, *et al*., 2011; Hussain, *et al*., 2021; Kasim, *et al*., 2015). Brown seaweeds in particular are reported for their use in the form of foliar spray for crops due to their nutritional and biochemical contents (Makawita, *et al*., 2021). Although the effects of SLF on a wide variety of plants including mung beans, black grams, sugarcane, spinach, brinjals among other vegetables (Zahid, 1999; Khan, *et al*., 2009; Shukla, *et al*., 2019) are reported from all over the world, studies related to tomato plants are still scarce (Yao, *et al*., 2020).

Tomatoes are one of the most important crops utilized throughout the world, including Pakistan (Tahir, *et al*., 2012). They are used in many forms as they are rich in vitamins A and C, minerals, and antioxidant compounds (Khalid, 2013). Although tomatoes can be grown in all four provinces (Khan, *et al*., 2023), their annual production in Pakistan is quite low as compared to other countries (Ahmed, *et al.,* 2022). The growth and yield of tomato plants can be increased by applying various fertilization techniques as well as by using high-quality seeds (Yusuf, *et al*., 2023). This research focused on the effects of brown seaweed *Sargassum tenerrimum* used as SLF on the physical parameters and yield of tomato plants.

2. METHODOLOGY

2.1 SAMPLE PREPARATION

Brown seaweed *S. tenerrimum* was collected from the Karachi coast during January-February 2023. Collected samples were brought to the laboratory, where they were washed with tap water to remove epiphytes, sand particles, and other debris. Washed seaweed was shade-dried, and then ground into a powder form for use.

The seeds of *Solanum lycopersicum* were collected from a local shop near the university. The seeds were imbibed in tap water for a couple of hours, after which 5 seeds were placed in each pot.

2.2 Experimental Design

Briefly, 10g of the seaweed sample was boiled with 100ml of distilled water for an hour and then filtered. This filtered extract was centrifuged at 3000rpm for 10 minutes. The resultant supernatant was filtered and considered as a stock solution (Bhosle, *et al*., 1975; Parab, & Shankardhawan, 2022).

Once the seeds of tomato plants had germinated, three different concentrations, 1%, 2%, and 3% made from the stock solution, were sprayed twice weekly, while the control received only tap water. Physical parameters, including shoot and root length, number of leaves, leaf area, total plant height, number of buds, flowers, and fruits, were recorded for five months. The whole experiment was carried out in triplicate.

3. RESULTS AND DISCUSSION

Tomatoes are used worldwide as they have vitamins A, B, and C, and high antioxidant activity due to the presence of high lycopene content (Noonari, *et al.,* 2015). Therefore, the current study focused on the effect of seaweed liquid fertilizer (SLF) obtained from brown seaweed *Sargassum tenerrimum* as SLF on the physical parameters and yield of tomato plants. The shoot length, number of leaves, and leaf area were observed weekly; therefore, weekly results are shown and discussed. The root length and total plant height were observed after harvesting the plants, and the results are described accordingly. The number of buds, flowers, and fruits was recorded weekly once present, but the data represent the mean value of observations of the studied parameters of each month. Except for the root length, where the plants treated with 1% concentration had the highest root length, 3% SLF concentration increased all other physical parameters, as well as the fruit yield of plants. Mzibra, *et al*., (2021) have suggested that seaweed extracts contain bioactive compounds, which activate plant signalling pathways likely responsible for enhancing nutrient uptake in tomato plants, leading to their overall better growth and yield. Elgubbi, *et al*., (2019) also concluded that since seaweed liquid fertilizers are safe to use on living organisms, they act as an eco-friendly approach to significantly increase in the yield and quality of tomato plants. The time frame of the current research spanned over a period of 20 weeks (Figure 1).

Figure 1. Plants treated with different concentrations of SLF (a), flowering and fruiting in plants treated with 3% SLF concentration (b and c).

3.1. Shoot Length

The 3% concentration of SLF had a prominent effect on tomato plants from the beginning, showing an initial shoot length of 6.94cm in the first week (the week in which the plants germinated). In the same week, 1% and 2% SLF-treated plants had maximum mean shoot lengths of 3.46cm and 3.9cm, respectively, while the shortest shoot length of 2.68cm was recorded in the control (Figure 2). Similar results were observed in the second week, where 3% SLF-treated plants had maximum shoot length (6.4cm), followed by 1% and 2% treated plants (4.8cm and 4.3cm), respectively, while the shortest shoot length was observed in the control (3.66cm). By the third week, control showed a slightly higher shoot length (5.04cm) as compared to 1% SLF (4.54cm), while 2% and 3% SLF concentrations had the shoot length of 5.22cm and 8.12cm, respectively. By the end of the first month, the shoot lengths of control and plants treated with 1%, 2%, and 3% SLF concentrations were 6.3cm, 5.94cm, 5.1cm, and 7.78cm, respectively. A study conducted by Rabhi, *et al*., (2024) has also described that higher concentration (15%) had a more prominent impact as compared to lower concentrations (5% and 10%) on the shoot length, fresh weight of shoot, and dry weight of both shoot and root. In this research, throughout December, the plants treated with 2% SLF concentration had the lowest growth rate of shoot, rising from 5.1cm in November to 7.68cm in the first week, 8.98cm in the second week, 10.6cm in the third week, and 11.68cm in the last week of December. The control plants showed little difference as compared to the 2% SLF treated ones, having mean maximum lengths of 7.68cm, 9.14cm, 10.54cm and 12.14cm, while 1% SLF treated plants had maximum shoot lengths of 8.68cm, 10.2cm, 11.88cm, and 13.5cm in the first, second, third and last week of December. The shoot length of plants treated with 3% SLF concentration increased gradually to 12.2cm in the first week of December, then 14.28cm, 16.54cm, and finally to 17.8cm in the final week of December. The shoot length of the same plants decreased to 14.02cm in the first week of January, but then increased to 27.7cm in the last week of January. Among the other concentrations tested, 1% SLF-treated plants increased from 13.5cm to 15.54cm in the first week, to eventually 22.22cm in the last week of January, while 2% SLF-treated plants increased shoot length from 11.68cm to 19.48cm in the first week to 24.4cm in the last week of January. The control had the shortest shoot length, increasing from 12.14cm to 13.78cm in the first week and to 19.52cm in the last week of January. In February and March, the plants treated with 3% concentration of SLF showed a prominent difference as compared to the control and other concentrations tested. The shoot length increased from 29.4cm at the start of February to 32.5cm at the end of the month. In March, the same plants grew 1.5cm each week, leading to a total height of 37cm at the time of harvesting. The plants treated with 1% and 2% SLF concentrations had little difference in their shoot lengths, but showed a notable difference compared to 3% treated plants ($p \leq 0.05$). In plants treated with 1% SLF concentration, the shoot length increased from 24.08cm at the start of February to 28.7cm at the end of the month, and finally to 32.8cm in the last week of March. 3% SLF-treated plants showed similar results, with a slightly higher growth rate. This growth rate increased from 25.6cm in the first week of February to 28.7cm in the last week, ultimately resulting in a shoot length of 33.2cm at the time of harvesting. The control plants had the lowest growth rate, increasing from 20.2cm at the start of February to 24.12cm in the last week of the month, and increasing to 27.94cm at the end of the experiment in the last week of March. Previously, Aymen, *et al*., (2014) treated two cultivars of tomato plants with seaweed extract of brown seaweed *Sargassum vulgare* in two different concentrations (0.2% and 0.5%), and observed that the 0.5% SLF concentration had a more prominent impact on the shoot length of plants, while the control plants had the shortest shoot length.

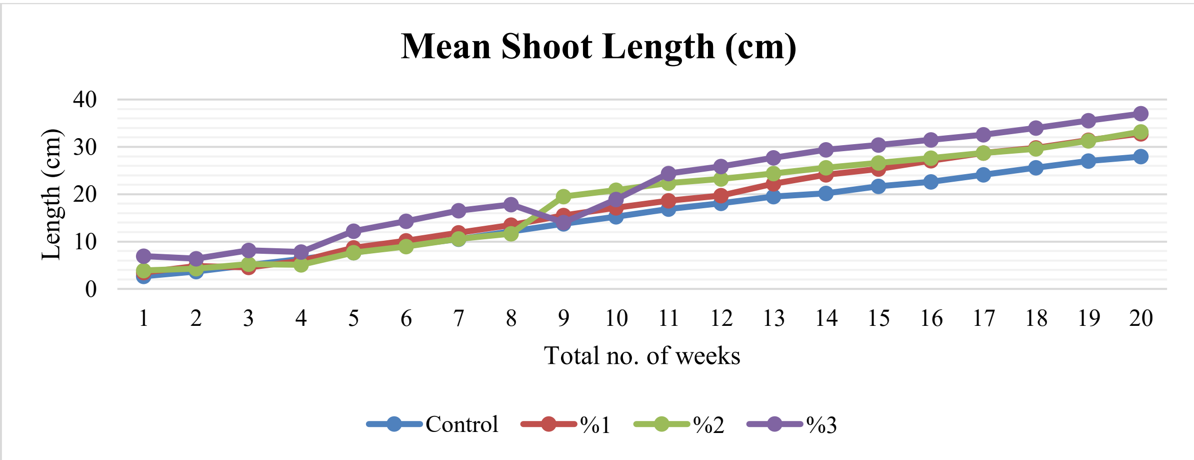

Figure 2. Weekly mean shoot length of tomato plants treated with different concentrations of SLF

3.2. Number of Leaves

Initially, the control plants along with the replicates treated with each SLF concentration (1%, 2%, and 3%) had 2 leaves in the first week of November (Figure 3). In the same month, the number of leaves in the control plants increased to 3 in the 2nd week, and to 4 in the last two weeks of the month. The plants treated with 1% and 2% SLF concentrations increased their number of leaves from two to three in the second week, five leaves in the third week, and 6 leaves per plant at the end of the month. 3% SLF concentration had the most profound effect on the plant leaves from the beginning, as the initial two leaves increased to five, six, and seven leaves in the second, third week, and last week of November. The same plants observed an increase of a single leaf in the second and final week of December, leading to eight leaves in the second and third weeks, and 9 leaves in the last week of December. Previously, Yusuf, *et al*., (2023) stated that seaweed liquid fertilizer obtained from *Sargassum*, when used in 50cc/L of water, caused a considerable increase in the number of leaves of tomato plants. In the current research, the plants treated with 2% SLF concentration increased their number of leaves from six to seven in the first two weeks, and then to eight in the last two weeks of December. While in the plants treated with 1% SLF concentration, eight leaves were observed throughout December. In the same period, the control plants had a minimum number of leaves; i.e, five in the first two weeks of December, and six in the last two weeks of December, as well as in the first two weeks of January. The same plants increased their number of leaves to seven in the next two weeks, and finally reached to eight-leaf stage by the end of January. Among the concentrations tested, the 2% SLF-treated plants had the least number of leaves from January (9) to February (11), and finally till the time of harvesting in March (13), while the 3% SLF-treated plants had the most number of leaves, ranging from nine to 11 eleven leaves in January, increasing to 13 in February, and showing a total mean of 16 leaves per plant in March. The number of leaves in plants treated with 1% SLF concentration increased from 8 to 11 in January, and to 13 leaves per plant by mid-March, showing a little increase as compared to 3% SLF-treated plants, but at the time of harvesting, they had fewer leaves as compared to those treated with 3%. This could be a result of an increase in temperatures towards the end of the month. The control plants increased their number of leaves from 8 to 10 in February, and increased to 11 in the last weeks of March. The more prominent effect of higher concentrations on the number of leaves was also observed by Lefi, *et al*., (2023), where 0.25% SLF obtained from brown seaweed *Ecklonia maxima* had a prominent effect on tomato leaves as compared to 0.1% SLF of the same seaweed.

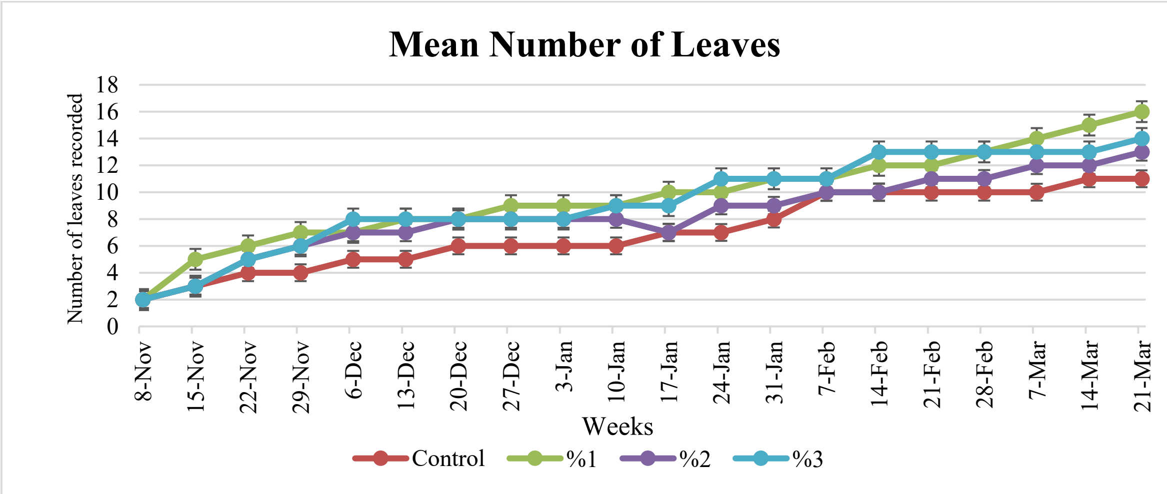

Figure 3. Weekly number of leaves in tomato treated with different concentrations of SLF

3.3. Leaf Area

The leaf area was calculated by measuring the length and width of leaves. The control plants had the lowest leaf area throughout the study (Figure 4). Previously, Subramaniyan, *et al*., (2023) showed in their study that, as compared to the control, the extracts obtained from brown seaweed *Ascophyllum nodosum* increased the leaf area of tomato plants, particularly when applied in a concentration of 5.0L/ha. In the present study, initially, the difference between the leaf areas of control and SLF-treated plants was low, as the leaf area of the control was 0.26 cm^2, while leaf areas of 0.78 cm^2, 1.04 cm^2, and 1.4 cm^2 were recorded for plants treated with 1%, 2%, and 3% SLF concentrations, respectively. The difference between control and other plants increased from the very next week (2nd week of November), as the leaf area of control plants increased from 0.26cm^2 to 0.6cm^2, 1.58cm^2, and then to 2.73cm^2 in November. The plants treated with 1% SLF concentration increased their leaf area from 0.78cm^2 to 1.4cm^2, 3.67cm^2 and 3.7cm^2 in November, 2% SLF treated plants increased the leaf area to 2.22cm^2, 4.07cm^2, and 6.55cm^2, while the plants treated with 3% SLF concentration increased their leaf area from 1.4cm^2 to 3.31cm^2, 6.73cm^2, and 9.76cm^2 in the second, third and fourth weeks of November. According to the study conducted by Murtic, *et al*., (2018), the plants of cherry tomatoes treated with extract obtained from *A. nodosum* have a larger leaf area as compared to the non-treated plants, irrespective of any other stress applied to the same plants. In this research, the same plants of 3% SLF-treated pots increased their leaf area to 10.05cm^2, 14.03cm^2, 16.07$cm^{2,}$ and 23.35cm^2 in the first, second, third, and fourth weeks of December. The plants treated with 2% SLF concentration showed similar results as those treated with 3% SLF, as their leaf area was recorded as 10.34cm^2 in the first week of December, and increased to 14.49cm^2, 19.09cm^2, and 20.65cm^2 in the next weeks of the same month. The plants treated with 1% SLF increased their leaf area from 6.5cm^2 in the first week to 7.98cm^2, 9.55cm^2, and 23.52cm^2 in the second, third and fourth weeks of December. The control plants had the lowest leaf area, increasing from 4.53cm^2 in the first week to 5.13cm^2, 7.37cm^2, and 12.04cm^2 in the next weeks of December. In the first week of January, the leaf area of plants treated with 1% and 2% SLF concentrations showed a slight increase (33.75cm^2 and 33.29cm^2) as compared to 3% SLF-treated plants (28.86cm^2). But from the second week of January, the plants treated with 2% SLF concentrations had the lowest leaf area among the three concentrations tested, ranging from 33.1cm^2 in the second week to 37.2cm^2, 49.69cm^2, and 45.75cm^2 in the third, fourth, and last weeks. The leaf area of 1% and 3% SLF-treated plants ranged from 35.03cm^2 and 35.31cm^2 in the second week, 46.69cm^2 and 49.35cm^2 in the third week, 53.34cm^2 and 53.66cm^2 in the fourth week, and 65.37cm^2 and 68.9cm^2 in the last week of the month. The plants treated with 3% SLF displayed a prominent difference in their leaf area in February, increasing from 74.95cm^2 in the first week to 89.45cm^2, 114.23cm^2 and 138.42cm^2 in the second, third and fourth weeks. The plants treated with 1% SLF concentration increased their leaf area to 71.18cm^2, 82.41cm^2, 99.32cm^2 and 113.85cm^2 in the four weeks of February. The 2% SLF treated plants had a slightly increased leaf area (55.31cm^2) as compared to the control in the first week of February (54.76cm^2), but in the remaining weeks of February, the control had higher leaf area (69.51cm^2, 91.12cm^2, and 100.63cm^2) than 2% (63.25cm^2, 74.59cm^2, and 91.82cm^2). However, in March, the leaf area of the control dropped to 91.88 cm² in the first week, and then increased to 94.56 cm² and 96.01 cm² in the second and third weeks, respectively. The 2% SLF-treated plants increased their leaf area to 116.7cm^2 in the first week, 142.09cm^2 in the second week, and 165.73cm^2 in the final week of March. The 1% and 3% SLF-treated plants had almost similar leaf area in the first week of March (131.04cm^2 and 131.302cm^2, respectively), but the plants treated with 3% SLF showed a notable increase in leaf area to 168.45cm^2 and 206.79cm^2 in the second and third week of March. While the leaf area of plants treated with 3% SLF increased to 148.24cm^2 and 167.2cm^2 in the second and final weeks of March.

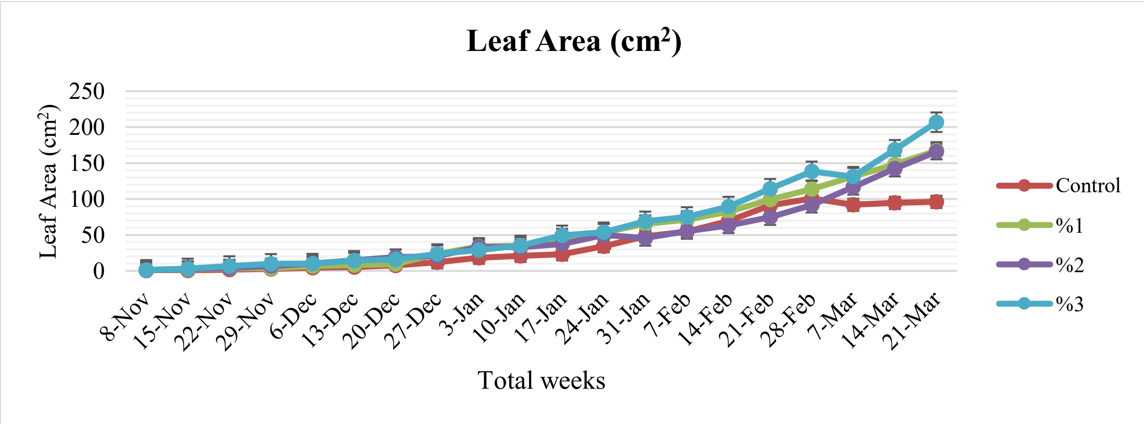

Figure 4. Showing the weekly leaf area of tomato plants under SLF treatments along with the control

3.4. Root Length

The root length and total height of plants were measured after they were harvested in March. The maximum length of root was observed in 1% concentration of SLF (10.56±0.86cm), while the least growth of root was observed in the control, which was 6.46±0.73cm. In contrast, 2% and 3% SLF concentrations had 7.9±0.9cm and 9.22±0.7cm mean root lengths, respectively (Figure 5). The study conducted by Herrera, *et al*., (2014) revealed that tomato plants treated with 1% concentrated SLF extracts obtained from brown seaweed *Sargassum horridum*, increased their radicle length by up to 6.7%. Anton, *et al.,* (2023) also reported in their study that a 0.2% concentrated seaweed extract obtained from green seaweed *Ulva ohnoi* can increase the root length of tomato plants by up to 25% as compared to the control plants.

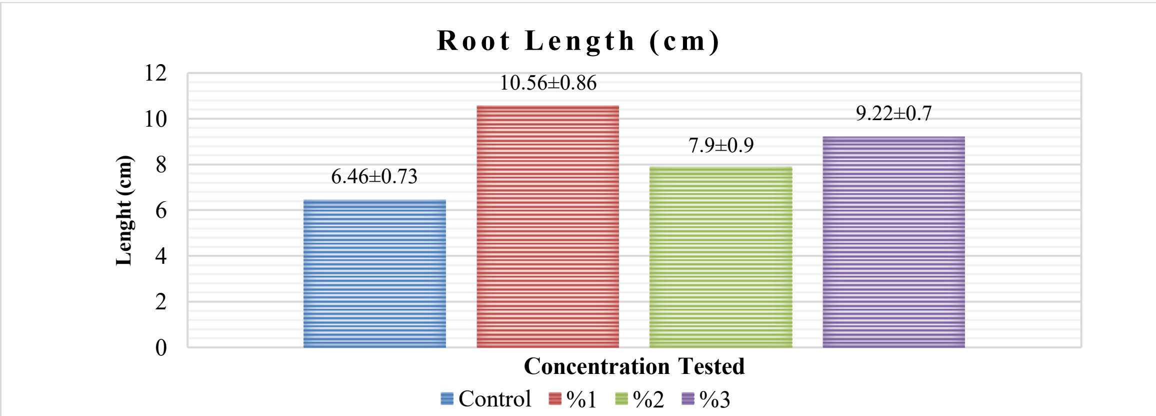

Figure 5. Root length (cm) tomato plants treated with different concentrations of SLF along with the control

3.5. Total Height

The maximum total height was 46.22±0.76cm, observed in plants treated with a 3% SLF concentration, followed by 1% SLF concentration (43.36±0.91cm) and 2% SLF concentration (41.1±0.79cm) ($p \leq 0.05$). The control plants showed distinct lower height (34.4±0.46cm) compared to the concentrations tested, indicating a positive impact of SLF obtained from *S. tenerrimum* (Figure 6). In a previous study conducted by Subramaniyan, *et al*., (2023), the tomato plants treated with 2.5L/ha, 5.0L/ha, and 10L/ha SLF extracts obtained from *Ascophyllum nodosum* showed a notable increase in their growth parameters in all the concentrations tested, although 5.0L/ha and 10L/ha SLF concentrations had a more prominent effect. In contrast, Herrera, *et al*., (2019) tested 0.2%, 0.4%, and 1% SLF extracts of green seaweed *Ulva lactuca* and brown seaweed *Padina gymnospora*, and concluded that 0.2% extracts of both seaweeds had a more profound effect on the total length of tomato plants.

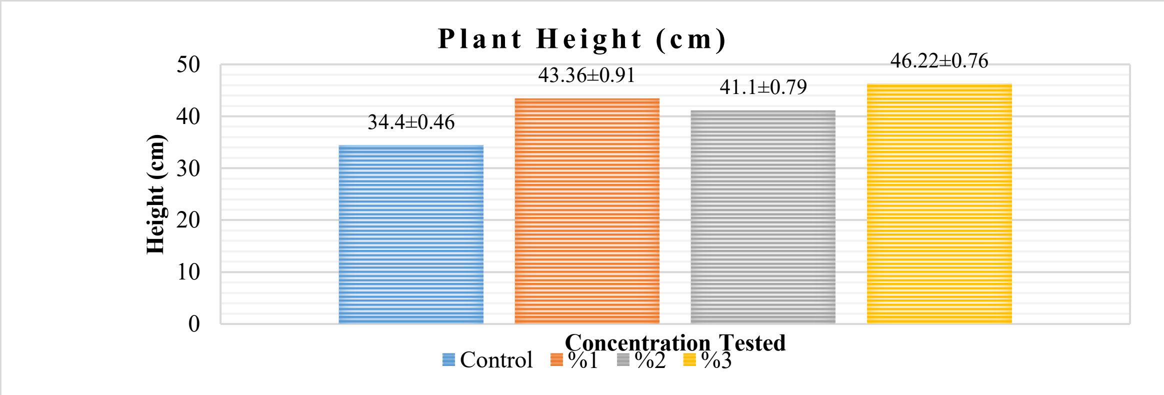

Figure 6. Total height (cm) of tomato plants treated with different concentrations of SLF along with control

3.6. Number of Buds, Flowers, and Fruits

It has been previously reported that seaweed extracts not only increase the overall yield of tomatoes, but also increase the amount of calcium present in tomatoes (Colla, *et al*., 2017). In this research, the maximum fruit yield was recorded in 3% SLF-treated plants in March at the time of harvesting, while buds in each concentration were observed since late December, a month and a half after the initial sowing of seeds, and the control plants didn't show any buds until late February (Table 1). In 1% and 3% SLF-treated plants, 4 buds were initially observed in December. In 1% SLF-treated plants, four buds were observed in the remaining months, as well. In contrast, 3% SLF-treated plants showed 8 buds in January, February, and March. The plants treated with 2% SLF concentration had 6 buds from December to March. All of the buds present 3% SLF-treated plants in December bloomed into flowers in January, while 7 buds bloomed in February, and all 8 buds present in March bloomed into flowers in the same month. Three fruits were harvested from 3% SLF-treated plants in January, seven in February, and eight in March. In 2% SLF-treated plants, 5 flowers bloomed in January, and 6 flowers in February, as well as in March. In the same plants, four fruits were harvested in January and 6 fruits each in February and March. Among the SLF-treated plants, the lowest number of flowers and fruits was observed in plants treated with 1% SLF concentration, as three buds bloomed into flowers in January and February, and only two buds bloomed in March. In the same treatment, two fruits were harvested in January, 3 in February and 3 in March. In control, a single bud emerged in mid-February, while two buds were observed in March. The bud observed in February in the control bloomed at the end of the same month, and started to develop into fruit, while only one bud bloomed in flower in March, eventually developing an immature fruit at the time of harvesting. Previously, Mzibra, *et al*., (2021) concluded in their study that in tomato plants treated with an extract obtained from brown seaweed *Fucus spiralis*, yield began fifteen days earlier compared to the control plants. Mannino, *et al*., (2020) also revealed that seaweed extracts not only caused early fruiting in tomato plants but also increased the quality of tomato yield.

Table 1. Number of buds and flowers present in each concentration tested

Conc.	No. of Buds				No. of Flowers			No. of Fruits		
	Dec	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
Control	0	0	1	2	0	1	1	0	1	1
1%	4	4	4	4	3	3	2	2	3	3
2%	6	6	6	6	5	6	6	4	6	6
3%	4	8	8	8	4	7	8	3	7	8

4. CONCLUSION

The study concludes that brown seaweed *Sargassum tenerrimum* possibly utilized as a potential source of SLF on tomato plants, as it enhances both physical parameters and fruit yield. Further studies on the biochemical aspects of tomato plants are recommended. Seaweed Liquid Fertilizers (SLFs) provide easy access to nutrients, vitamins, and trace elements to plants; therefore, these fertilizers can lead to creating to an overall better yield and quality of crops. As this is a baseline study, further experiments with more replicates will bear fruitful results in increasing the yield of tomatoes through SLF.

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