Journal of
Agriculture and Biology
ISSN: 3007-1755 (Print), 3007-1763 (Online)

Research Article

Exploring Seaweed Potential to Induce Cold Resistance in Tomato

Muhammad Junaid Bashir[1], Tanveer Ahmad[1*], Muhammad Usman Khan[1], Muhammad Abu Bakar Saddique[2], Syeda Anum Masood Bokhari[1], Muhammad Tariq[1], Hamid Ishtiaq[1], Mudassar Naseer[3], Abid Mahmood Alvi[4]

[1] Department of Horticulture, Muhammad Nawaz Shareef University of Agriculture, Multan
[2] Institute of Plant Breeding and Biotechnology, Muhammad Nawaz Shareef University of Agriculture, Multan.
[3] Senior Scientist (Horticulture), Horticultural Research Station Sahiwal.
[4] Department of Plant Protection, Ghazi University, DG Khan.

ABSTRACT

Tomato is a member of the Solanaceae family, one of the most significant vegetable crops worldwide. Tomato fruit is a rich source of vitamins, minerals, dietary fiber and essential amino acids. Cold stress is an important limiting factor for tomato cultivation, leading to reduced growth, yield and quality. Thus, the purpose of this research was to investigate, how tomato growth, development, productivity and tolerance to abiotic stress specifically, cold stress was improved by seaweed (*Ascophyllum nodosum*) extract. Various concentration of seaweed extract was given to the tomato plants as T_0 (control), T_1(5mg/L), T_2(10 mg/L), T_3(20 mg/L), T_4(25 mg/L) and T_5 (30 mg/L). This study was carried out to measure the foliar application of seaweed on tomato crop yield during winter season 2023-24. A randomized complete block design (RCBD) was used in this experiment. Results regarding the plant height, number of branches, number of flower, number of fruit per plant, fruit length, fruit diameter and fruit weight. Results showed that the highest plant height LY-36, Pi-7 and Naqeeb followed by LY-47 were observed the T5 (30mg/L). Results showed that the maximum number of flower and fruit Pi-1 followed by Pi-13, Pi-7, Naqeeb and Sahel were observed the T5 (30mg/L). On the other hand, maximum fruit diameter LY-47 followed by CWO-4 were observed T5 (30mg/L). The result showed the maximum fruit weight CWO-4 followed by LY-48 were observed T5 (30mg/L). The findings give a positive correlation between tomato resistance and cold stress. Hence, seaweed extract at the rate of 30 mg/L is recommended for cultivation of tomato under cold conditions.

Keywords: Seaweed, Genotype, Cold stress, Growth, Yield.

OPEN ACCESS

Correspondence
Tanvir Ahamd
tanveer.ahmad@mnsuam.edu.pk

Article History
Received: October 13, 2024
Accepted: November 28 2024
Published: December 30, 2024

INTRODUCTION

The Tomato is the world's most highly consumed summer vegetable it is most valuable component of many cooked, raw and processed foods (Babalola et al., 2010). In Pakistan, tomatoes are important crops, grown predominantly in Sindh, Punjab and Baluchistan (FAO, 2017). Tomato fruit are most vulnerable to bacterial and fungal degradation after harvest due to their increased activity of water, favorable pH, and rich in nutrition, all of which serves as a growth nutrient for microorganism's growth (Safari et al., 2021). Bacterial deterioration is indicated by appearance of sour rot and soft rot on tomato surface (Das et al., 2020; Spricigo et al., 2021). To cope this short shelf life, there are many postharvest approaches, i.e., hypobaric, modified atmospheric packaging, controlled atmospheric storage (CA), and coating with edible materials are widely used (Olveira-Bouzas et al., 2021; Paulsen et al., 2019; Pristijono et al., 2017).Organic coating materials are increasingly being used in the post-harvest treatment of tomatoes to improve their shelf life and thus maintain quality. These coatings work by producing barriers that restricts moisture loss and gas exchange, thereby slowing respiration and delaying ripening (Elsabee and Abdou, 2013). Similarly, Aloe Vera Gel; known for its biocompatibility and biodegradability and creates a protective layer that retain moisture and delays the ripening process (Valverde et al., 2005).

Gum Arabic; natural gum forms a film on the tomatoes. This reduces transpiration and respiration, and hence tomatoes shelf life is improved (Ali et al., 2010). Natural coatings of neem, aloe vera, ginger, garlic and distilled water on tomatoes have remarkably affected shelf life as well as quality. Below are the results with enhanced effects of each coating are tabulated in details: (Kumar et al., 2008). Aloe vera gel is widely known for its hydrating and healing properties. Its biocompatibility and biodegradability also make it a very good coating material that can extend the shelf life of fresh produce. The aloe vera gel was helpful in maintaining tomatoes' low weight loss and texture and preserving sensory traits during storage (Valverde et al., 2005). Ginger extract is rich in bioactive compounds, including gingerol and shogaol, possessing huge antimicrobial and antioxidant activities. After coating the tomatoes with it, the ginger extract can heavily limit microbial contamination that causes spoilage. Being antimicrobial, it regulates the growth of the microorganisms that would have caused spoilage, whereas its antioxidant activity prevents the development of oxidative stress and prolongs the shelf life of the produce against premature senescence (Singh et al., 2014). Since the garlic extract consists of allicin, a compound which is strongly known to possess antimicrobial activity, garlic-extract coating on tomatoes may reduce microbial loads, which may include bacteria and fungi, which often cause spoilage (Yin and Cheng, 2003).

Use of seaweeds has been common in Britain, Spain, Roman Empire, China, Japan, France etc. Seaweeds extract is in use as a biofertilizer in most coastal areas across the globe for crop production. It is also used in seed treatment, soil application and foliar spray for plant growth and plant protection. Because of its non-toxic, eco-friendly and bio-decomposable nature, it is more beneficial than chemical fertilizers for sustainable agriculture in organic and integrated organic farming. It is known to improves the fruit setting, nutrient incorporation, resistance for biotic and abiotic factors (Mukherjee and Patel, 2020). No such study has been documented till date about the wholesome and minute study regarding the effect of natural seaweed extract on tomatoes in Pakistan. Hence, the objective of current investigation was exploring the impact of natural seaweed extract coating on the quality of tomato fruits under room temperature.

MATERIALS AND METHODS

Plant material

The tomato genotype was collected from University of Agriculture Faisalabad Pakistan, and imported from China. A total of 30 Genotypes were used in this experiment to identify high yield genotypes in tomato.

Experiment site

These genotypes were sown in plug trays in October 2023. After one-month old seedlings were transplanted in the research area of MNS University of Agriculture, Multan (MNSUAM). The climate in this region is subtropical with an average annual rainfall of 175 mm,88% of which July to September. This monthly average temperature ranges from 21 C January to 38 C in April and maximum average temperature range from June.

Layout and experimental condition

The genotypes were sown in accordance with Randomized Complete Block Design (RCBD). These genotypes were sown in plug trays in October 2023. After one-month old seedlings were transplanted in the research area of MNS University of Agriculture, Multan (MNSUAM) following the randomized complete block design (RCBD) in three replications. Transplanting was done with the help of a planter on the distance of 45 cm between plants and 75 cm between beds.

Table 1. Concentration of Seaweed extract

Treatments	Concentrations
T0	Control
T1	5 mg/L
T2	10 mg/L
T3	20 mg/L
T4	25 mg/L
T5	mg/L

Here T = Treatments, mg = milligram, L = one litter of distilled water

Data collection for morphological traits

Data for "plant height" of six plants from each genotype in each replication were collected from the soil surface to shoot tip by measuring tape. The "number of branches per plant" in tomatoes refers to the total count of primary stems that develop from the main stem of a tomato plant. "Number of flower" first step of fruit production, flowering is an important part of a tomato plant's life cycle. The "number of fruit per plant" in tomatoes refers to the count of mature, harvestable fruits produced by an individual tomato plant during its growing season. "Fruit length" in tomatoes refers to the measurement of the distance from the base to the tip of a tomato fruit along its longest axis, typically expressed in centimeters (cm). "Fruit diameter" in tomatoes refers to the measurement of the widest part of the tomato fruit across its circumference, typically expressed in millimeters (mm). The data were calculated after harvesting the tomato fruits by vernier caliper scale. "Ten fruit weight" in tomatoes refers to the mass of an individual tomato fruit, typically measured in grams (g). After harvesting, five fruits from each replication were taken randomly and weight were measured by using digital physical balance having readability of about 0.01 gram manufactured by “OHASU Corporation. USA”.

Statistical Analysis

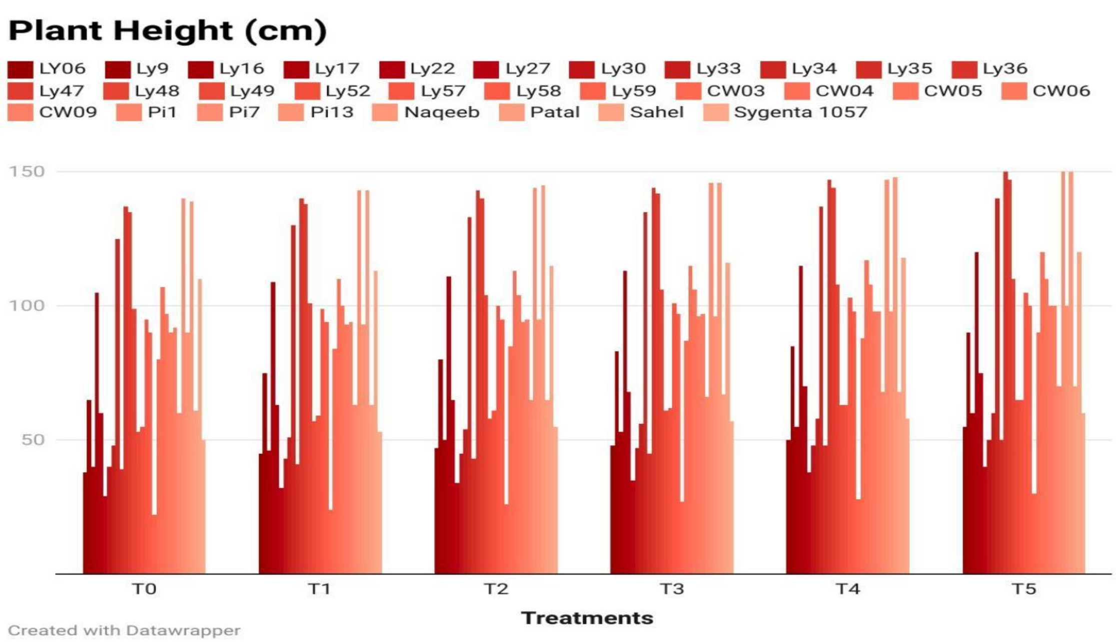
The data was analysed for Analysis of variance (ANOVA) and significant differences among the genotypes was determined through mean comparison test i.e Tuckey & LSD test at 5% significance level through a statistical software (Steel *et al.*, 1997)

RESULTS

Morphological parameters

Plant Height (cm)

Treatments comparison of seaweed have significant effect on the plant height, when the data was subjected to analysis of variance. Results showed that the maximum plant height (T_5) followed by(T_4) was attained by foliar application of seaweed (30mg). There was also a clear tendency that as the concentration (30mg) of seaweed increased, the plant height of the tomato (Figure 1). While minimum plant height was observed in the control treatment (T_0) and the genotype comparison of seaweed of the highest number of branches show that the results LY-36, Pi-7 and Naqeeb (150cm) followed by LY-47 (147cm). On the other hand, LY-59 (22cm) followed by LY-27 (29 cm) lowest genotype of the tomato, which was significantly lower than that of the other genotype (Figure 2).

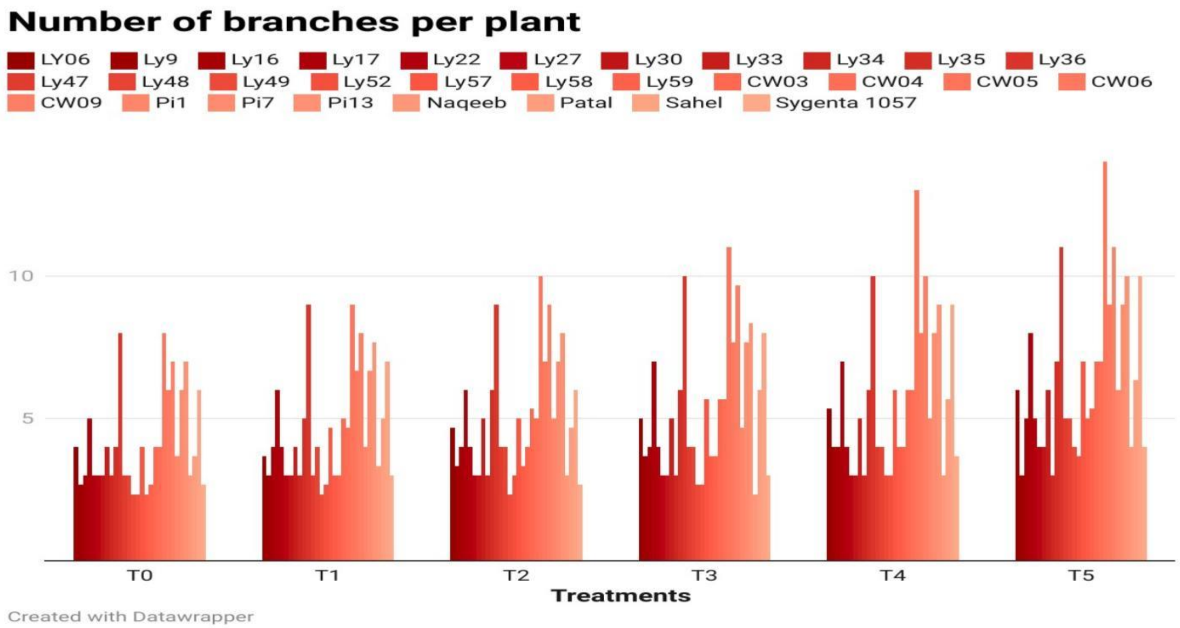


T_0= (Distilled water), T_1= (5mg/L), T_2= (10mg/L), T_3= (20mg/L), T_4= (25 mg/L) and T_5= (30 mg/L)

Figure 1. Exploring Seaweed Potential to Induce Cold Resistance plant height of Tomato

Number of Branches

Treatments comparison of seaweed have significant effect on number of branches, when the data was subjected to analysis of variance. Results showed that the highest number of branches (T_5) was attained by foliar application of seaweed (30mg). There was also a clear tendency that as the concentration of 30mg of seaweed increased, the number of branches on the tomato (Figure 2). While minimum number of branches was observed in the control treatment (T_0) and the genotype comparison of seaweed of the highest number of branches show that the results CWO-5 (14). On the other hand, LY-49 (2.33) lowest genotype of the tomato, which was significantly lower than that of the other genotype (Figure 2). They grow fast with branches spreading almost randomly, although they may have an erect growth habit depending on the strain and the region such plants occupy. Phytohormones like cytokinins, auxins, and gibberellins, which control a range of physiological activities in plants like development and growth and stress reactions, are found in seaweed extracts.

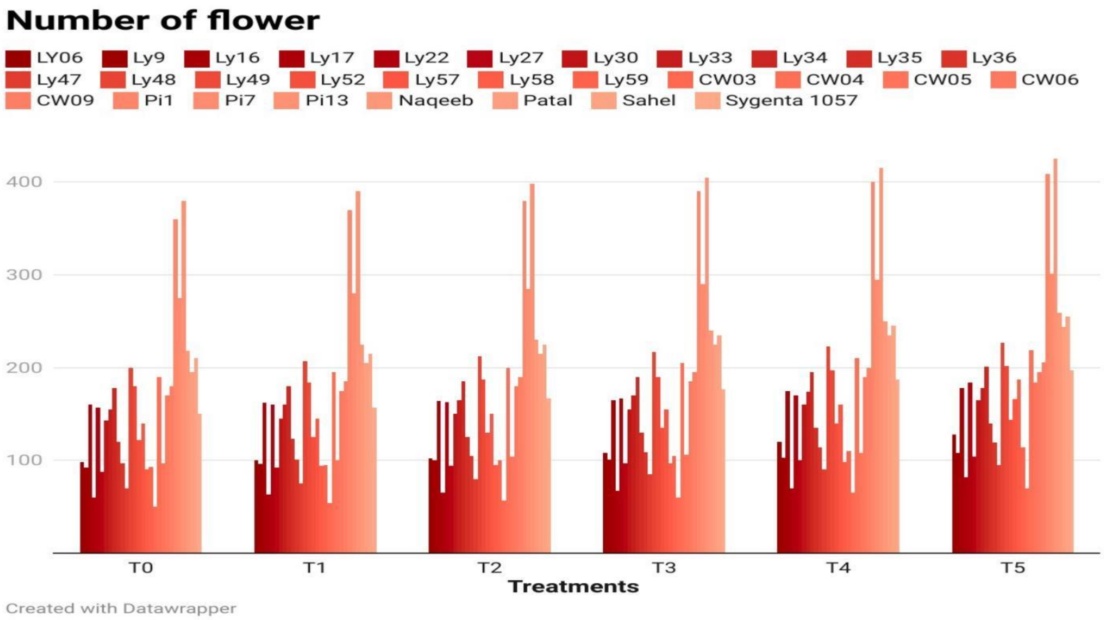


T_0= (Distilled water), T_1= (5mg/L), T_2= (10mg/L), T_3= (20mg/L), T_4= (25 mg/L) and T_5= (30 mg/L)

Figure 2. Exploring Seaweed Potential to Induce Cold Resistance number of branches per plant of Tomato

Number of flower

Treatments comparison of seaweed have significant effect on the number of flower, when the data was subjected to analysis of variance. Result regarding the maximum number of flower was noticed in T5 where 30mg of seaweed were used which was much higher than any other treatment (Figure 3). On the other hand, a minimum number of flower was noticed in T_0 where control (distilled water). While the genotype comparison seaweed of the maximum number of flower shows that the results Pi-13 (425) followed by Pi-1 (409), Pi-7 (301), Naqeeb (259) and Sahel (255). On the other hand, CWO-3(50) followed by LY-47 (70) and LY-27 (88) lowest genotype of the tomato, which was significantly lower than that of the other genotype (Figure 3).

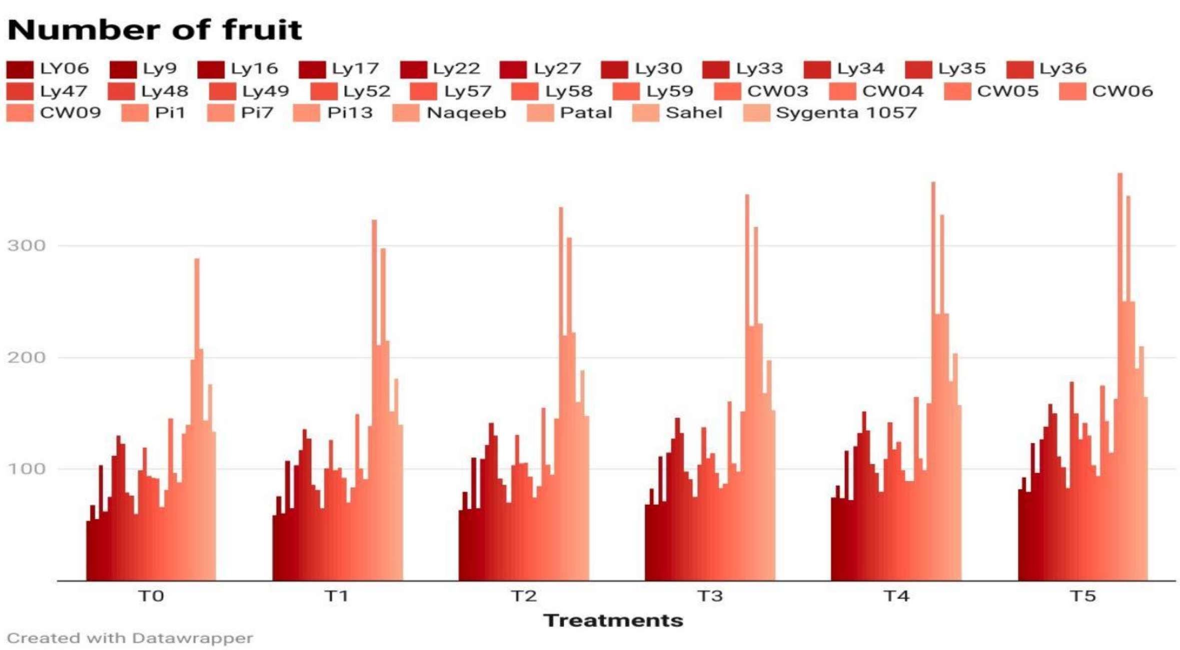


T_0= (Distilled water), $T_{1=}$ (5mg/L), $T_{2=}$ (10mg/L), $T_{3=}$ (20mg/L), $T_{4=}$ (25 mg/L) and $T_{5=}$ (30 mg/L)

Figure 3. Exploring Seaweed Potential to Induce Cold Resistance number of flower of Tomato

Number of fruit per plant

Treatments comparison of seaweed have significant effect on the number of fruit per plant, when the data was subjected to analysis of variance. Result regarding the maximum number of fruit per plant was noticed in T5 where 30mg of seaweed were used which was much higher than any other treatment (Figure 4). On the other hand, a minimum number of fruit per plant was noticed in T_0 where control (distilled water) (Figure 4). While the genotype comparison seaweed of the maximum number of fruit per plant shows that the results Pi-1 (365) followed by Pi-13 (345), Pi-7 (250), Naqeeb (250) and Sahel (210). On the other hand, Ly-6(53.66) followed by LY-47 (60) and LY-27 (68) lowest genotype of the tomato, which was significantly lower than that of the other genotype (Figure 4).



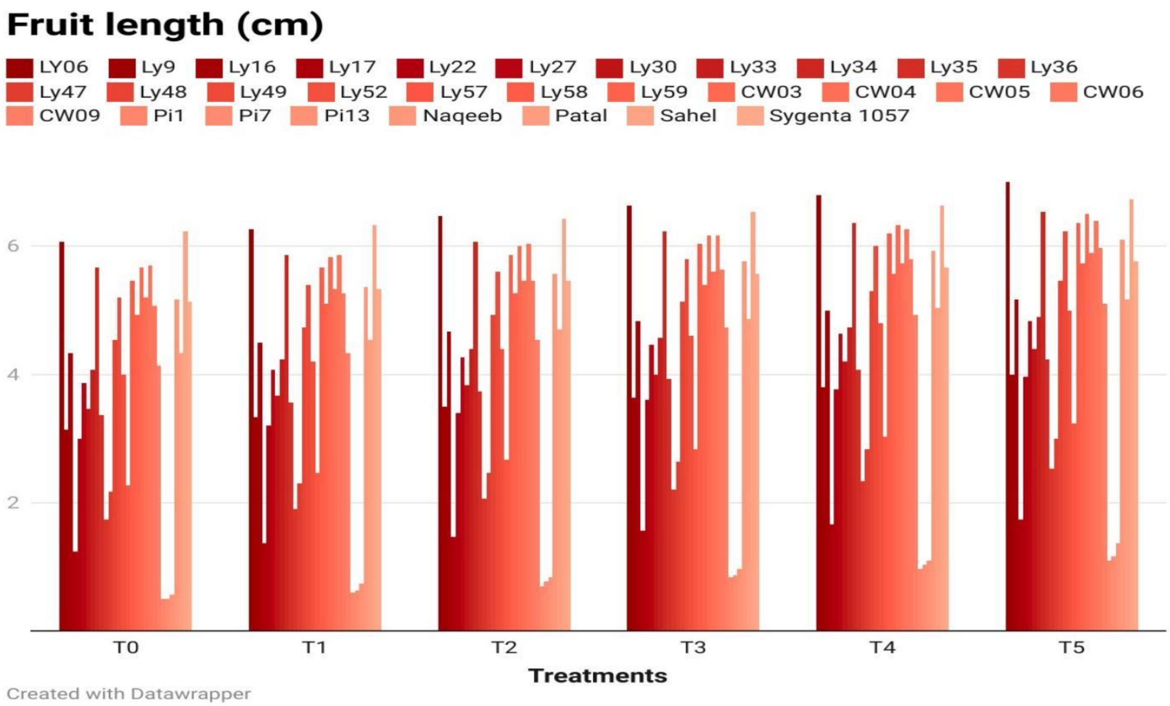
T_0= (Distilled water), $T_{1=}$ (5mg/L), $T_{2=}$ (10mg/L), $T_{3=}$ (20mg/L), $T_{4=}$ (25 mg/L) and $T_{5=}$ (30 mg/L)

Figure 4. Exploring Seaweed Potential to Induce Cold Resistance number of fruit per plant of Tomato

https://doi.org/10.55627/agribiol.002.02.1005

Fruit length (cm)

Treatments comparison of seaweed have significant effect on the fruit length, when the data was subjected to analysis of variance. Result regarding the maximum fruit length was noticed in T5 where 30mg of seaweed were used which was much higher than any other treatment (Figure 5). On the other hand, a minimum fruit length was noticed in T_0 where control (distilled water) (Figure 5). While the genotype comparison seaweed of the maximum fruit length shows that the results LY-6 (7cm) followed by Sahel (6.73cm), LY-34 (6.53cm), LY-49 (6.23cm) and Syngenta 1057 (5.76cm). On the other hand, Pi-1(1.1cm) followed by Pi-7 (1.16cm) and Pi-13 (1.36cm) lowest genotype of the tomato, which was significantly lower than that of the other genotype (Fig.5). The results indicated the efficiency of the treatments where increasing the plant growth and yield and enhancing the cold tolerance in the treated plants from the untreated controls.

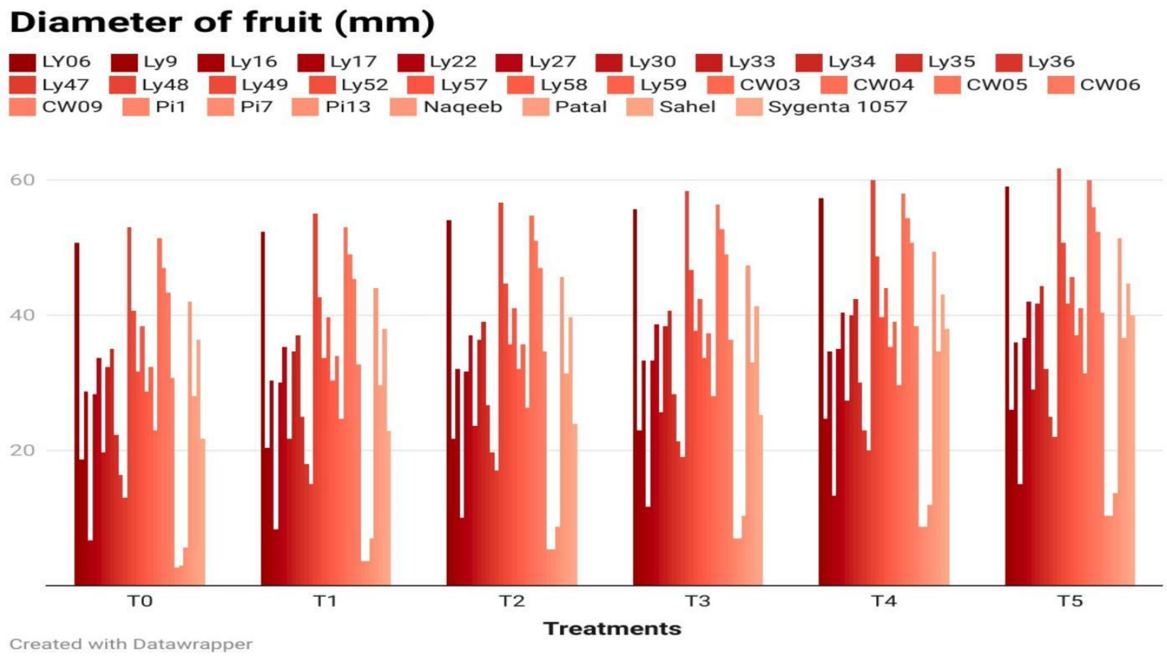


T_0= (Distilled water), $T_{1=}$ (5mg/L), $T_{2=}$ (10mg/L), $T_{3=}$ (20mg/L), $T_{4=}$ (25 mg/L) and $T_{5=}$ (30 mg/L)

Figure 5. Exploring Seaweed Potential to Induce Cold Resistance fruit length of Tomato

Fruit diameters (mm)

Treatments comparison of seaweed have significant effect on the fruit diameter, when the data was subjected to analysis of variance. Result regarding the maximum fruit diameter was noticed in T5 where 30mg of seaweed were used which was much higher than any other treatment (Figure 6). On the other hand, a minimum fruit diameter was noticed in T_0 where control (distilled water). While the genotype comparison seaweed of the maximum fruit diameter shows that the results LY-48 (61.66mm) followed by CW0-4 (60mm), LY-6 (59mm), and LY-49 (52.33mm). On the other hand, Pi-1(2.66mm) followed by Pi-7 (3mm), Pi-13 (5.66mm) and LY-17 (6.66mm) lowest genotype of the tomato, which was significantly lower than that of the other genotype (Figure 6).

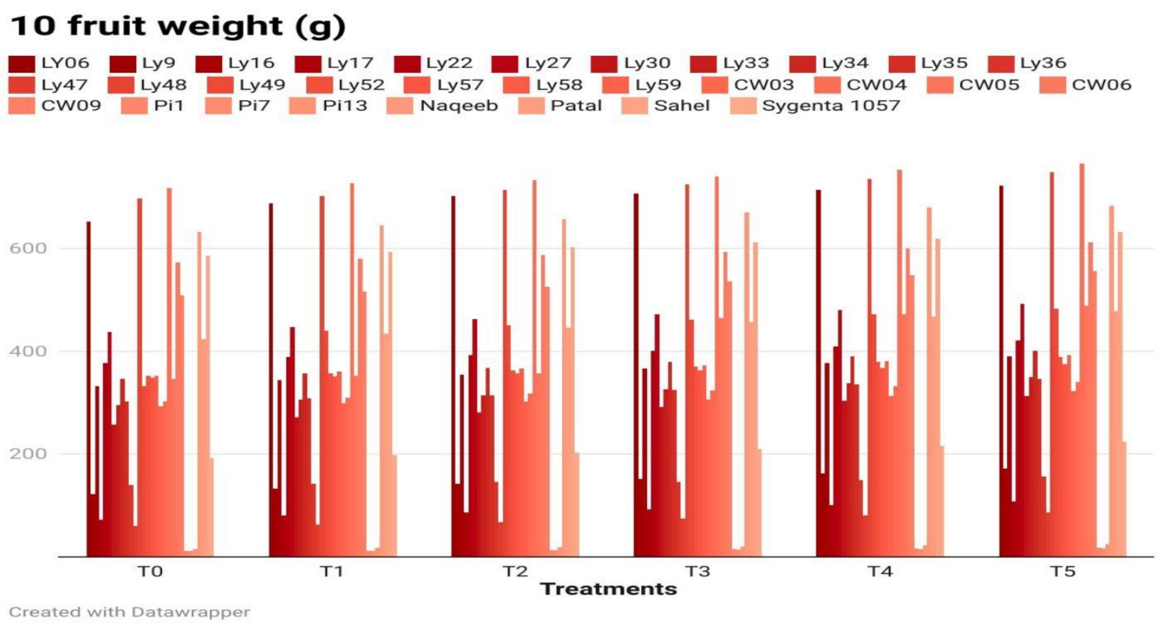


T_0= (Distilled water), $T_{1=}$ (5mg/L), $T_{2=}$ (10mg/L), $T_{3=}$ (20mg/L), $T_{4=}$ (25 mg/L) and $T_{5=}$ (30 mg/L)

Figure 6. Exploring Seaweed Potential to Induce Cold Resistance fruit diameter of Tomato

Fruit weight (g)

Treatments comparison of seaweed have significant effect on the fruit weight, when the data was subjected to analysis of variance. Result regarding the maximum fruit weight was noticed in T5 where 30mg of seaweed were used which was much higher than any other treatment (Figure 7). On the other hand, a minimum fruit weight was noticed in T_0 where control (distilled water). While the genotype comparison seaweed of the maximum fruit weight shows that the results CW0-4 (764.33g) followed by LY-48 (748.33g), LY-6 (722g), Naqeeb (682.33g) and Sahel (632.33g). On the other hand, Pi-1(11.3g) followed by Pi-7 (11g), and Pi-13 (15g) lowest genotype of the tomato, which was significantly lower than that of the other genotype (Figure 7).



T_0= (Distilled water), $T_{1=}$ (5mg/L), $T_{2=}$ (10mg/L), $T_{3=}$ (20mg/L), $T_{4=}$ (25 mg/L) and $T_{5=}$ (30 mg/L)

Figure 7. Exploring Seaweed Potential to Induce Cold Resistance fruit weight of Tomato

DISCUSSION

The findings of this study demonstrate that the application of seaweed extract significantly enhances the growth and yield parameters of tomato plants. Among the various treatments, T5 (30 mg of seaweed extract) consistently outperformed all other treatments, including the control (T0), across multiple morphological and reproductive parameters. These results are consistent with previous studies that highlight the efficacy of seaweed extracts as bio-stimulants in promoting plant growth and productivity due to their rich composition of phytohormones, trace minerals, and bioactive compounds (Craigie, 2011; Khan et al., 2009).

T5 had the highest plant height with genotypes LY-36, Pi-7, and Naqeeb showing tall plants, hence high responses to the treatment. The cell elongation and vascular differentiation were reported to increase by Goñi et al. (2018), making the plants taller. On the other hand, the lowest height of LY-59 calls for a genotype-specific response in future application.

Growth in the branching was significantly enhanced in T5-treated plants. More counts of branches were observed on the genotype CWO-5, with minimal increase occurring on LY-49. This is in agreement with Khan and Zhai, 2019, suggesting that phytohormones in extracts of seaweeds enhance lateral growth, hence leading to increased branching. Results confirm the seaweed extracts work for increasing vegetative growth in all genotypes.

Reproductive parameters, such as flowers and fruits per plant, increased under T5 treatment. Pi-13 and Pi-1 genotypes produced the maximum flowers and fruits, respectively, which was in support of earlier findings where the authors correlated seaweed treatments with better flowering and fruiting through enhanced hormonal balance and stress tolerance (Khan et al., 2009; Rayirath et al., 2008). These increases are important for maximum fruit yields in stressful environments.

The treatments have a great impact on fruits' size and weight because these are the most quality- determining parameters. T5-treated plants produced the longest and heaviest fruits, with genotypes LY-6 and CW0-4 being the best. Zhou et al. (2020) observed that the extracts of seaweed reduced cold stress and increased cell enlargement, making the fruits bigger in size. However, minimum improvement was reported in genotypes Pi-1 and Pi-7, indicating that genetic factors may influence the treatment effectiveness.

This study therefore confirms the fact that extracts of seaweed improve growth and yields of tomatoes by modifying the physiological characteristics. Other related research studies also illustrate the beneficial effects of bio-stimulants derived from seaweed on uptake of nutrients, stress resistance, and productivity (Craigie, 2011; Deribe et al., 2016). Future studies should focus on optimizing application methods and rates for different genotypes and environments to maximize the benefits of seaweed extract treatments for sustainable agriculture.

CONCLUSION

The current investigation shows that seaweed and genotype both influence to use extracts of seaweed as bio stimulants so that the tomato plant is capable of withstanding cold situations. The effectiveness of the seaweed extract was also tested towards cold tolerance with several physiological, chemical and molecular studies to establish how the cold tolerance is enhanced in plants. The tomato genotypes exhibited significant variations in growth against different treatment and showed the best result on T_5 with 30 mg/L seaweed extract. All the genotype had the highest plantlet survival rate, suggesting a genotype-specific response of cold resistant. The maximum plant height Ly-36, Naqeeb and Pi-7 followed by Ly-47. Maximum number of flower and fruit Pi-1 followed by Pi-13, Pi-7, Naqeeb and Sahel. The findings give a positive correlation between tomato resistance and cold stress. Hence, seaweed extract at the rate of 30 mg/L is recommended for cultivation of tomato under cold conditions.

ACKNOWLEDGEMENTS

The Tomato plant material for this research work was provided by University of Agriculture Faisalabad Pakistan, and imported from China. All authors highly appreciate and sincerely thank them for their generous facilitation and support for this study.

AUTHOR CONTRIBUTIONS

This MSc (Hons.) research study with the experimentation and manuscript original drafting was done by Mr. Muhammad Junaid Bashir, conceptualization and supervision of the study; Dr. Tanveer Ahmad and Mr. Muhammad Usman Khan, methodology; Dr. Abu Bakar Sadique, data analysis; Dr. Syeda Anum Masood Bokhari, Muhammad

Tariq, Hamid Ishtiaq, Mudassar Naseer and Abid Mahmood Alvi supported in improving, editing and proof reading the manuscript.

COMPETING OF INTEREST

There is no conflict of interest and all authors approved the submission of this manuscript.

REFERENCES

Chaudhary, J., Khatri, P., Singla, P., et al 2019. Advances in omics approaches for abiotic stress tolerance in tomato. *Biology*, 8: 90.

Craigie, J.S., 2011. Seaweed extract stimuli in plant science and agriculture. *J. Appl. Phycol.*, 23(3): 371–393.

Deribe, H., Beyene, B., 2016. Review on pre and post-harvest management on quality tomato (*Lycopersicon esculentum* Mill.) production. *Food Science and Quality Management*, *54*(1), 72-79.

Elbadrawy, E., Sello, A., 2016. Evaluation of nutritional value and antioxidant activity of tomato peel extracts. *Arabian Journal of Chemistry*, *9*, S1010-S1018.

FAO. 2021. FAOSTAT Database: Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/faostat/en/#home.

Goñi, O., Fort, A., Quille, P., et al 2018. Comparative transcriptome analysis of two *Ascophyllum nodosum* extract biostimulants: Same seaweed but different. *J. Appl. Phycol.*, 30(6): 3327–3337.

Jithesh, M.N., Shukla, P. S., Kant, P., et al 2019. Physiological and transcriptomics analyses reveal that *Ascophyllum nodosum* extracts induce salinity tolerance in *Arabidopsis* by regulating the expression of stress-responsive genes. *J. Plant Growth Regul.*, 38: 463–478.

Khan, R.I., Hafiz, I.A., Shafique, M., et al 2018. Effect of pre-harvest foliar application of amino acids and seaweed (*Ascophylum nodosum*) extract on growth, yield, and storage life of different bell pepper (*Capsicum annuum* L.) cultivars grown under hydroponic conditions. *Journal of Plant Nutrition*, *41*(18), 2309-2319.

Khan, W., Zhai. R., 2019. Biochemical and molecular basis of seaweed-induced growth promotion in plants. *J. Plant Growth Regul.*, 38(3): 770–784.

Khan, W., Rayirath, U. P., Subramanian, S., et al 2009. Seaweed extracts as biostimulants of plant growth and development. *J. Plant Growth Regul.*, 28(4): 386–399.

Liu, Y., Zhang, C., Hu. Q., 2022. Seaweed-based biostimulants for enhancing crop resilience under abiotic stress: Current status and future perspectives. *Plants*, 11(2): 161.

Mukherjee, A., Patel, J.S., 2020. Seaweed extract: biostimulator of plant defense and plant productivity. *Int. J. Environ. Sci. Technol.,* 17: 553–558.

Perveen, R., Suleria, R.A.H., Anjum, M. F., et al 2015. Tomato (*Solanum lycopersicum*) carotenoids and lycopene chemistry; metabolism, absorption, nutrition, and allied health claims: A comprehensive review. *Crit. Rev. Food Sci. Nutr.*, 55(7): 919–929.

Rayorath, P., Jithesh, N. M., Farid, A., et al 2008. Rapid bioassays to evaluate the plant growth promoting activity of *Ascophyllum nodosum* (L.) Le Jol. using a model plant, Arabidopsis thaliana (L.) Heynh. *J. Appl. Phycol.*, 20(3): 423–429.

Scott, J.W., Jones, B.J., Somodi. C.G., 2019. Tomato disease and pest management for tomato transplants grown in the greenhouse. Univ. Florida IFAS Extension. Retrieved from https://edis.ifas.ufl.edu/cv216

Siddiqui, M.H., Khan. N.M., 2021. Seaweed-based biostimulants and their role in improving plant productivity under stress conditions. *J. Plant Nutr. Soil Sci.*, 184(4): 477–490.

Stirk, W.A., Tarkowská, D., Turečová, V., et al 2014. Abscisic acid, gibberellins and brassinosteroids in Kelpak®, a commercial seaweed extract made from Ecklonia maxima. J. Appl. Phycol., 26(2): 561–567.

Vinha, A.F., Alves, C.R., Barreira, V.S., et al 2014. Effect of peel and seed removal on the nutritional value and antioxidant activity of tomato (*Lycopersicon esculentum* L.) fruits. *LWT-Food Sci. Technol.*, 55(1): 197–202.

Zhou, M., Luo, X, Zhou, X., et al 2020. Comprehensive analysis of differentially expressed genes and transcriptional regulation induced by low and high temperature in tomato. *Front. Plant Sci.*, 11: 576409.