J. Appl. Res Plant Sci. Vol. 5(2), 160-169, 2024, https://doi.org/10.38211/joarps.2024.05.247

Research Article

OPEN ACCESS

Available on https://www.joarps.org
Journal of Applied Research in Plant Sciences
(JOARPS)
ISSN: 2708-3004 (Online), 2708-2997 (Print)

Growth and Yield Response of Okra (*Abelmoschus esculentus* L.) to Various Levels of Biostimulant

Ghulam Nabi Khaskheli[1], Noor-un-Nisa Memon[1], Afifa Talpur[1], Muzamil Farooque Jamali[1], Ali Raza Jamali[1], Mariam Khaskheli and Muhammad Mithal Lund[1],

[1]Sindh Agriculture University Tandojam, Pakistan
Corresponding Author: nnmemon@sau.edu.pk

Article Received 25-12-2023, Article Revised 10-03-2024, Article Accepted 28-04-2024.

Abstract

The plant growth and productivity are threatened by poor soil conditions due to excessive use of inorganic fertilizers and abiotic stresses like salinity, drought, and high temperatures. The biostimulants are typically organic chemicals given to plants to increase nutrition efficiency and enhance tolerance against abiotic stresses and plant quality traits. Therefore, the current study was designed in 2023 to explore the effects of biostimulant on the growth, flowering and yield related parameters of okra. In this regard, biostimulant (Quantis Syngenta company) was used as a seed priming agent with different time periods of soaking. Biostimulant was used at 5-, 10-, 20- and 40-ml L^{-1} and seeds were soaked in each biostimulant solution for 8, 16 and 24 hours. The untreated seeds were treated as control. The experiment was conducted in a Randomized Complete Block Design (RCBD) with three blocks. The results determined that the okra treated with 40 ml L^{-1} of biostimulant had greater values for seed germination, plant height, branches $plant^{-1}$, days to flower initiation, pods $plant^{-1}$, seeds pod^{-1}, pod length, pod diameter, pod weight and pod yield $plant^{-1}$ as compared to other biostimulant levels and control. In case of soaking time periods, 24 hours resulted maximum seed germination, plant height, branches $plant^{-1}$, minimum days to flower initiation, pods $plant^{-1}$, seeds pod^{-1}, pod length, pod diameter, pod weight, and pod yield $plant^{-1}$. It is concluded from the present study that the seed priming with biostimulant at 40 ml L^{-1} had significantly greater values for growth and yield related parameters.

Keywords: Okra, Biostimulant, priming, growth, yield

Introduction

Okra (*Abelmoschus esculentus* L.) commonly called ladyfinger is a plant of Malvaceae family. A warm-season vegetable crop grown in the several regions of the world; this plant is originally from tropical Asia and Africa (Gamede *et al*., 2015). This plant is commonly cultivated in the plain areas of Punjab and Sindh provinces. Punjab climate came later than Sindh where the Okra is grown throughout the whole year (Saghir *et al*., 2012) and farmers get the benefit of growing the okra with higher rates and earn more than Punjab area grower (Bukhari, 2020). Okra possesses an enhanced nutritional quality, this plant is rapid to grow in raised temperatures, lending its cultivation to world's tropical side. Ladyfinger's top 4 cultivating countries are India, Nigeria, Mali and Pakistan (FAOSTAT, 2023). Okra is the best vegetable crop in Pakistan. During 2018 the okra total cultivated area in Pakistan was 15713 ha registering 120637 tons production (FAOSTATE, 2018). Okra is also grown in Khyber Pakhtunkhwa Province with an area of 16809 hectares with a production of 2083 tons, respectively but the average pod yield of okra in the province is very low. Share 1.3 % in world production of okra (Khan *et al*., 2022). Pakistani cities where okra is highly grown are Lodhran, Jhang, Vehari, Rahim yar khan, Toba Tek Singh, Muzaffarghar, Gujranwala, Rajanpur, D.G. khan, Multan, Okara, Faisalabad and Rawalpindi (Bilal & Zubair, 2018).

This vegetable is mainly cultivated for its 'pods' which are cooked and eaten in all over the world. This crop is highly nutritive and rich source of protein and considered as a low-fat food. Int contains fibers, minerals, vitamin C, folate, Vitamin B1, B6 and K. It also contains bioactive components such as flavonoids (Khan *et al*., 2023) Mucilage of this plant is used as a medicine for the treatment of gastric irritations (Dantas *et al*., 2021), and it possess approximately 20% of consumable oil and protein (Anwar *et al*., 2011). This plant is potent enough to raise people's income in towns and countryside areas and it is considered as the center of crucial nutrients which are fat free and possess low calories (Khan *et al*., 2023). The fruit of this plant offers significant antioxidant properties, principally because of abundant quantities of vitamin C, carotenoids, and flavonoids, it possesses healing properties against diabetes, hyperlipidemia, microbes, ulcers and neurodegenerative diseases (Uwiringiyimana *et al*., 2024). Okra is primarily grown by seeds with timespan of 3 to 4 months. It is cultivated in season of rain and spring. Spring season's okra is sown in February-March and in rainy season; it is cultivated in June-July. The fruits are ready to harvest after 60 to 70 days of sowing. Summer crop usually takes 100 & 90 days. This plant develops well in sandy loam soils having proper drainage. For getting excellent outcome of okra, the soil pH should be maintained from 6.0 to 6.8. Summer season crops are extremely delicate to frost. For okra's best cultivation perfect temperature is 25-30^{0}C (Chittora *et al*., **2017)**. In times of environmental changes this crop is typically grown and can encourage food security, Abiotic and biotic stresses are being a trouble for okra like several other crops (González *et al*., 2022). For modern times plants stress caused abiotically is an issue for their development and cultivation. Stresses caused by abiotic factors for instance aridity, saline level, and intensity of temperatures could be accountable for high losses of plant across the globe (Singh & Takhur. 2018). Abiotic stress tolerance, nutrient absorption, and general plant growth and development are all improved by the use of biostimulants, which are compounds or microbes that are administered to plants to accelerate natural processes. According to Damalas *et al*. (2019) reported that biostimulant is as a microbe (beneficial or harmful) or material given to soil or plants with the intention of improving crop quality and nutrient efficiency. The "mechanism of action" classifies the biochemical processes that occur after application, while the "mode of action" separates a bioactive molecule's primary properties from the biochemical process that defines the molecule's impact on treated plants (Aliferis *et al*., 2015). The majority of biostimulants (PBs) lack a particular influence on a distinct biochemical or regulatory mechanism certainly, there are very little PB products with recognized biochemical focused location and established method of operation. These are available in the market include seaweek, fungi, bacteria, animals, higher plants and humate containing raw material (Ahmad & Pitchtel, 2008). Identification of each regulator's receptor site and clarification of the following reactions are necessary for comprehending the molecular basis of PBs' mechanism of action. However, since these standards are difficult to meet, this level is often not met in these items. The processes of numerous PBs are still mainly unclear since the basic chemicals used to make them are diverse (Rafiee *et al*., 2016; Yakhin *et al*., 2017). These are different from conventional fertilizers in that they improve the plant's capacity to absorb and use nutrients rather than giving the plant the nutrients directly (Nurshant *et al*., 2021) as they provide a viable strategy for sustainable crop production, the use of biostimulants in agriculture has attracted increasing attention. Plant extracts, seaweed, microbes, and humic compounds are a few of the sources from which biostimulants may be obtained (Mrid *et al*., 2021). The management of biostimulants can be done in multiple ways, like seed treatments, soil additives, and foliar sprays (Bulgari *et al*., 2019). Despite the potential advantages of biostimulants, there are still several difficulties in their usage, including the need for further study to improve their use and efficacy and the lack of standards in the regulation and labeling of biostimulant products. In conclusion, biostimulants provide a viable strategy for environmentally sound crop production, with potential advantages for plant development, stress tolerance, and sustainability. To completely comprehend the mechanisms of action and maximize their application in various crop production systems, more study and development are necessary (Halpern *et al*., 2015; Oosten *et al*., 2017). Biostimulants are those materials which can occur naturally or can be man-made, these materials can be employed to seeds, also to the plants, and these can be employed to soil. Such materials promotes variation in procedures structurally for the purpose to impact growth of crop through improved tolerance to stresses caused abiotically and enhanced standard and outcome of grain or seed. Moreover, fertilizer requirement has lessened with biostimulants, biostimulants are available in variety of formulations such as seaweed extracts, contain identifiable amounts of active plant growth substances such as auxins, cytokinins, or their derivatives (Jardin, 2015). Amounts of plant Little quantities of these materials are resourceful, raised efficiency of nutrition, endurance to abiotic stress, and standard plant traits, irrespective to the content of nutrients. These material when employed externally showed same operations of popular hormones of plants, primarily auxins, gibberellins, and cytokinin (Agudelo-Morales *et al*., 2022). The substances which vary from conventional fertilizers of phosphorus (P), nitrogen (N), and potassium (K), possess diversity of hydrocarbon based compounds in formula, such as materials derived from seaweed, amino acids, humic acids, Vitamin C, which differs as per its producer (Yaronskaya *et al*., 2006). The experiment was therefore planned to explore the effects of biostimulant concentrations on the growth and yield of okra.

Materials and methods

The experiment was executed under the agro-ecological conditions of Tandojam, Sindh Pakistan located at 25^{o}25' 60'N 68^{o}31' 60E 19.5 m with average temperatures of 28.2 to 30.7^{0}C and humidity 37-38%. The study was run in 2023 at Sindh Agriculture University, Tandojam for observing okra's growth and yield response to various concentrations of biostimulant. The soil was clay loam and experiment was implemented under three blocks in Randomized Complete Block design possessing a net sub-plot size of 5 m^2. A perfect seedbed was made by embracing endorsed practices for preparation of land. Single dose of 30 kg nitrogen and 60 kg phosphorus at bottom was incorporated during preparation of soil. Nitrogen in the form of urea and phosphorus in the form of Diammonium phosphate was applied. Nitrogen was spilted into two doses one at the time of soil preparation and rest at the time of flowering was applied. Sub-division was done by dividing blocks into 3 beds. 30 cm wide bunds were used to separate beds. Sowing of seeds was done on ridges with method of dibbling. All agronomic practices and safe-guarding measures for each plot were consistently kept up.

Experimental factor: The Quantis a biostimulant of Sygenta company was used at different concentrations/levels with different soaking time periods. The quantis is a naturally derived biostimulant incorporating a combination of organic carbons, potassium, calcium and energy source carbohydrates, in the form of sugars and amino acids. The various concentrations of quantis 5, 10, 20 and 40 ml L^{-1} were prepared and seeds soaked in quantis solution for 8, 16 and 24 hours. The untreated seeds were treated as control. The Sarsabz seeds of the variety Okra were maintained 30 seeds per concentration and replication wise 90 seeds. The experiment was run in Randomized Complete Block Design.

Data collection and methodology: The data was collected for seed germination, vegetative parameters, reproductive and fruiting parameters.

Vegetative and germination parameters: The seed germination percentage was recorded on weekly basis and calculated on the basis of following formula.

$$Seed\ germination\ (\%) = \frac{\sum n}{N}\ x100$$

Where n signifies the quantity of germinated seeds recorded at each count and N indicates overall seeds in every treatment.

The height of the 50% plants from each specific treatment was measured randomly through measuring scale with scheduled gap of 15 days over of growing duration. Number of branches of randomly picked 50% plants from every specific treatment was counted and averages were done.

Reproductive and fruiting parameters: The random picking of 50% plants from every single treatment was monitored thoroughly for flowering initiation every week. Particular days from plantation till flower initiation were tracked and averages were calculated. The days from plantation up to the initiation of the fruiting were counted and averages were calculated. Furthermore, tagging was done for Random 50% plants selected by each treatment and these tagged plant's fruits were chosen for harvest and were counted. An average was number of pods $plant^{-1}$. Number of seeds pod^{-1} of 50% random samples from each treatment was counted and there by average was done. Additionally, pod length was measured from tip of fruit to the end of fruit with measuring scale in (cm) and average was calculated. The diameter of pod was observed in 50% random samples of each particular treatment, it was figured out with digital vernier caliper. Then random pod samples of each tagged plant was harvested and weighted on an electronic weighing balance for finding single pod weight an average was calculated. At the final harvest of crop, the pod yield $plant^{-1}$ was tracked in each specific treatment and later on the average was computed.

Yield per plant = sum of total number of harvests/Number of harvests

Statistical analysis: The data was analysed through statistical methods with the usage of statistix version 8.1 computer software (Statistix, 2006). Mean differences in treatments were found comparison by least significant difference (LSD) was done at significant level (P ≥0.05).

Results

Seed germination (%): Okra seed germination had significant difference for varying quantis levels and soaking time periods. Both factors had seed germination of more than 70% or closer to it (Figure 1). The interactive effect of quantis levels and soaking time periods had no significant difference for seed germination at probability level of 5%. The seeds treated in 40 ml L^{-1} of quantis solution had maximum seed germination (87.09%) that significantly followed by the results (80.94%) obtained from 20 ml $^{L-}$1 quantis. While the minimum seed germination (62.40%) was recorded under control. To compare soaking periods, 24 hours was observed better for good seed germination (76.83%) as compared to 16 (74.77%) and 8 (72.70%) hours, respectively.

Plant height (cm): The data in Figure 2 depicts that the plant height of okra had significant variation due to the varying quantis levels and soaking time periods, while both factors had no significant interaction at probability level of 5%. The treatment 40 ml L^{-1} maximized the okra plant height (111.06 cm) and significant reduction in the plant height from 111. 06 to 97.11 cm was observed with the decreasing quantis levels from 40 to 5 ml L^{-1}. While the shortest plants were recorded from control (92.48 cm). The results further showed that the plant height of okra soaked for 24 hours was greater (103.31 cm) as compared to 16 hours (101.76 cm) and 8 hours (100.22 cm).

Number of branches $plant^{-1}$: The data on number of branches $plant^{-1}$ of okra is mentioned in Figure 3. The data reveals that branches $plant^{-1}$ had no interactive significant effect of both the factors (quantis levels and soaking time periods). While as an independent factors, both had highly significant differences for number of branches $plant^{-1}$. The seeds treated with quantis for 24 hours produced plants with more number of branches (4.32) significantly followed by 16 (4.15) and 8 (4.00) hours, respectively. Quantis level was used from 5 to 40 ml L^{-1} and maximum quantis level exhibited more number of branches (5.12) and this number of branches decreased with decreasing level of quantis. The minimum number of branches were observed from control (3.18).

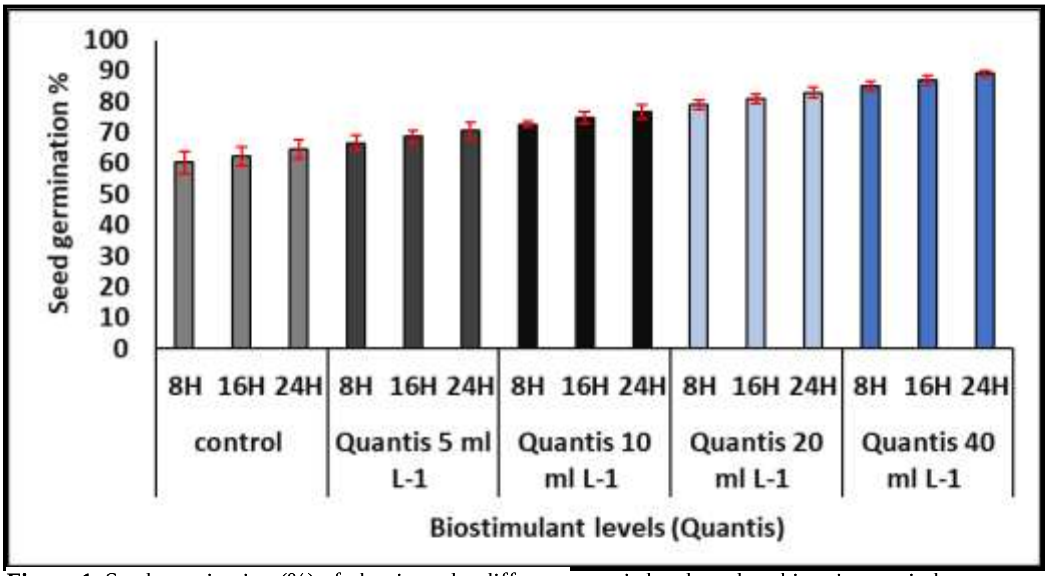

Figure 1. Seed germination (%) of okra in under different quantis levels and soaking time periods

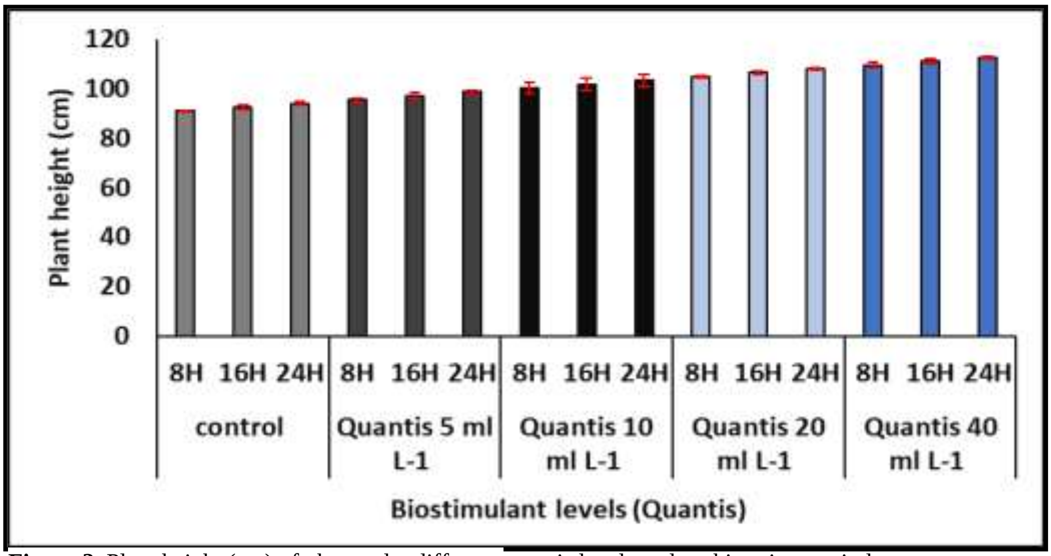

Figure 2. Plant height (cm) of okra under different quantis levels and soaking time periods

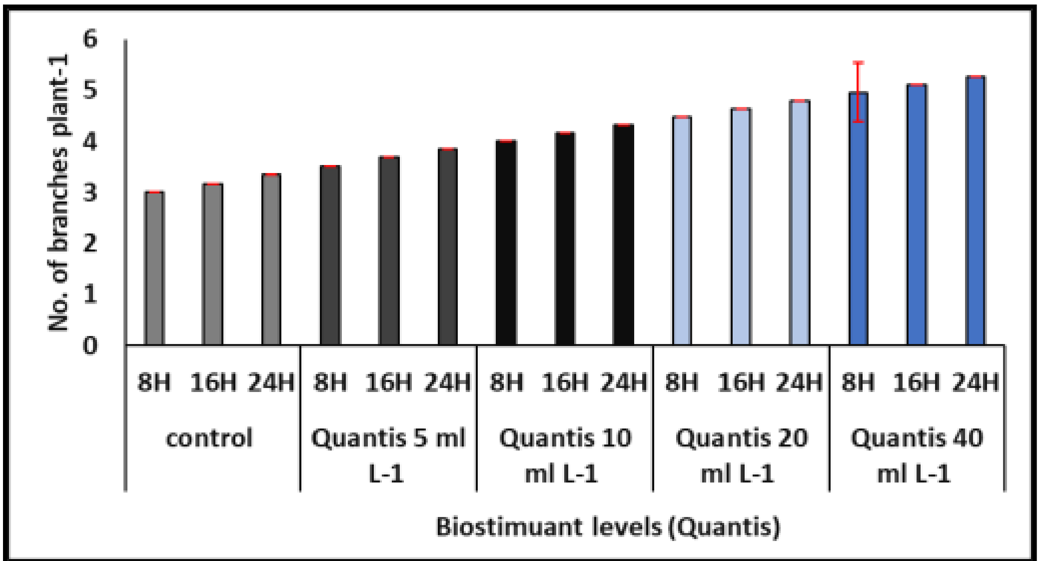

Figure 3. Number of branches plant^{-1} of okra under different quantis levels and soaking time periods

Days to flower initiation: The data on flower initiation is mentioned in Figure 4 and it reveals that control plants produced flowers earlier (45.56 days) than rest of all biostimulant treatments. However, flower initiation had significant differences as affected by varying quantis levels. The seeds treated with 40 ml L^{-1} quantis solution took more days (62.98) to initiate flowers and decreased the days with reducing levels of quanits. Soaking periods also affects flower initiation significantly. The 8 hours soaking of seeds, produced plants and took lesser days to flower initiation (52.82 days) while soaking of 24 hours delayed flower initiation upto 55.72 days

.

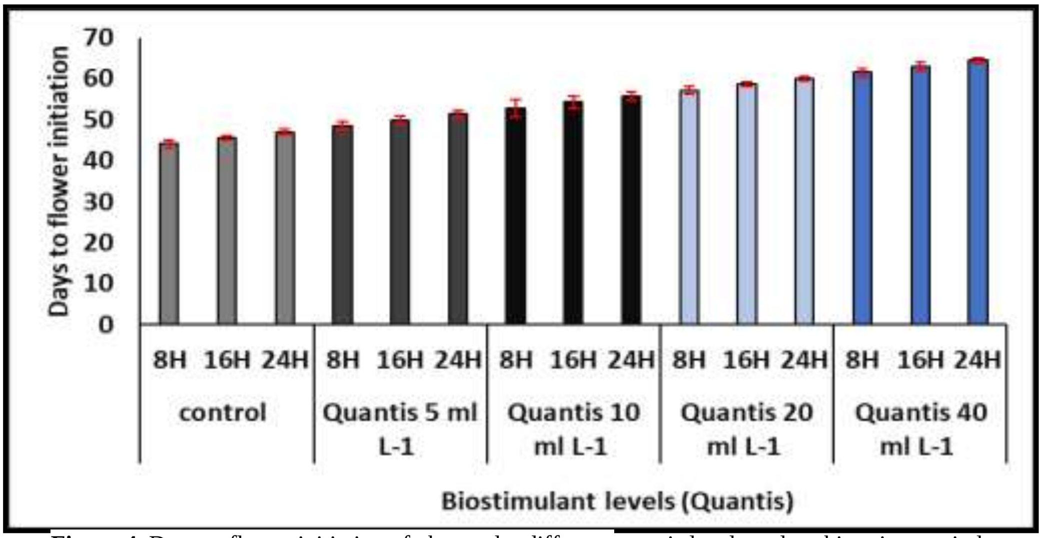

Figure 4. Days to flower initiation of okra under different quantis levels and soaking time periods

Number of pods plant^{-1}: The number of pods plant^{-1} of okra treated through varying levels of quantis and soaking time period and the results are reported in figure 5. The quantis levels and soaking time periods had significant effects for number of pods plant^{-1} as an independent factor. While their interaction was observed non-significant. The seeds treated with quantis level of 40 ml^{-1} produced plants with more number of pods (23.67) as compared to rest of the treatments. Number of pods were observed decreased with reduced levels of quanits. Least number of pods plant^{-1} (15.04) was computed under control . The results further showed that the number of pods plant^{-1} of okra soaked for 24 hours was greater (20.07) as compared to 16 hours (19.35) and 8 hours (18.63).

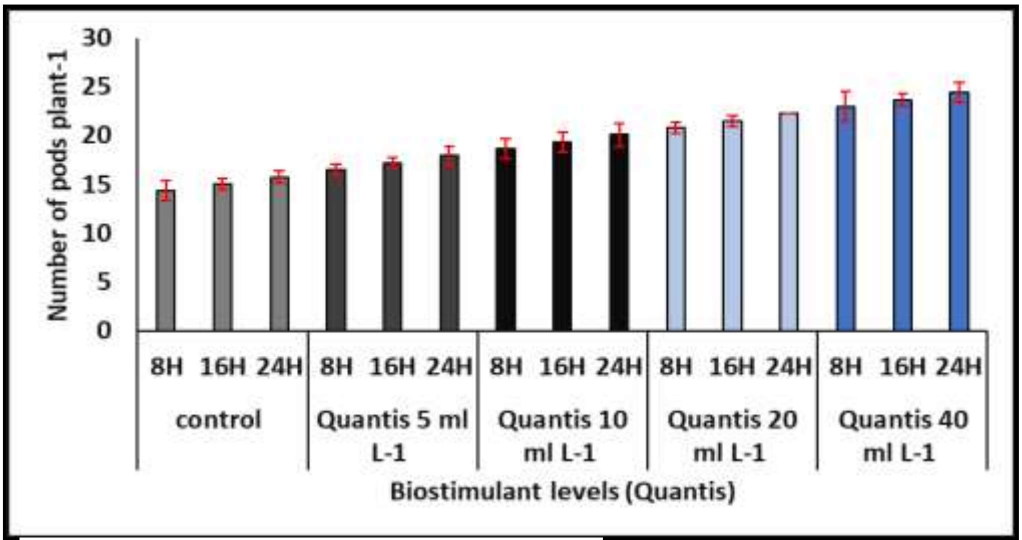

Figure 5. Number of pods plant^{-1} of okra under different quantis levels and soaking time periods

Number of seeds pod^{-1}: The number of seeds pod^{-1} of okra was significantly affected by the independent factos viz. quantis levels and soaking time periods. While the interactive effect of both the factors is non-significant as shown in Figurer 6. Number of seeds per pod is much correlated with the pod length and it ranges from 32.17 to 64.68. About quantis levels, 40 ml L^{-1} treated seeds produced pods with maximum number of seeds (64.68) and minimum number of seeds pe pod was observed from control. To compare soaking periods, 24 hours soaking got good number of seeds per pod (51.79) significantly followed by 16 (49.46 seeds) and 8 (47.17 seeds) hours.

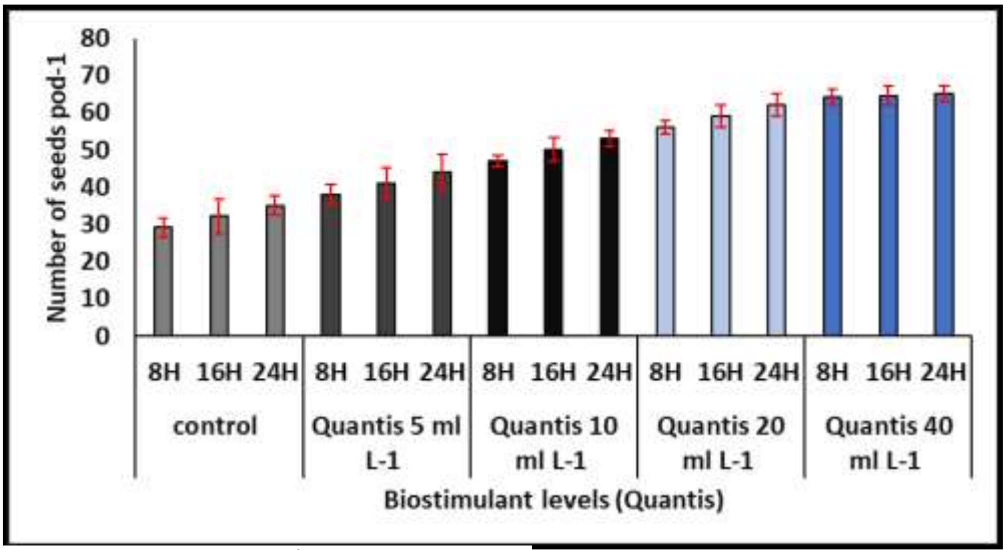

Figure 6. Number of seeds pod^{-1} of okra under different quantis levels and soaking time period

Pod length (cm): The pod length of okra treated through varying quantis levels and soaking time period is reported in Figure 7. Pod length was affected by quantis levels and soaking periods independently, while interaction was observed non-significant. To compare pod length among quantis levels, pod length was observed minimum (9.04 cm) in response to the lowest quantis solution of 5 ml L^{-1} significantly increased with 10 ml L^{-1} (10.66 cm), 20 ml L^{-1} (12.28 cm) and 40 ml L^{-1} (13.90 cm), respectively. Overall minimum pod length (7.38 cm) was observed from control.The results further showed that the pod length of okra soaked for 24 hours was greater (11.19 cm) as compared to 16 hours (10.65 cm) and 8 hours (10.11 cm).

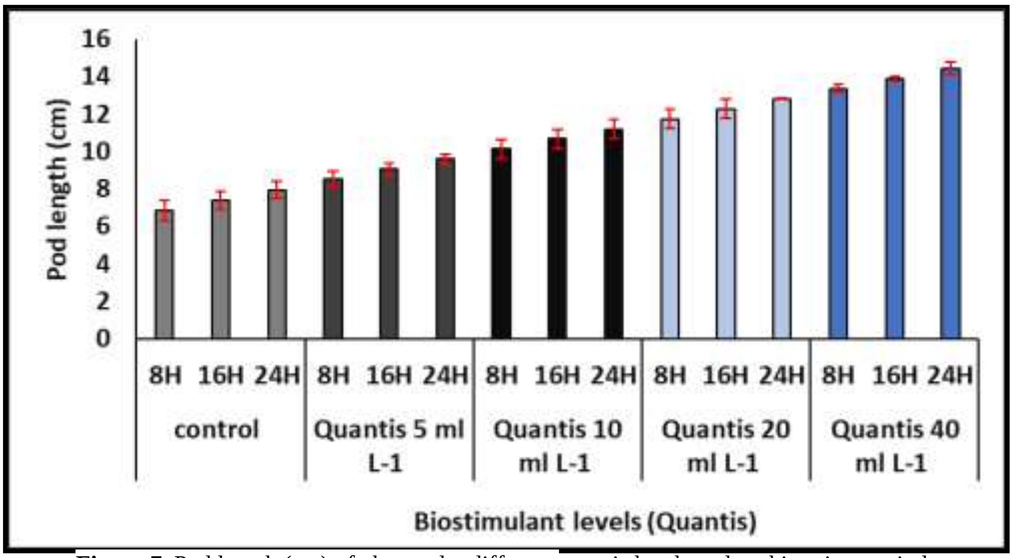

Figure 7. Pod length (cm) of okra under different quantis levels and soaking time periods

Pod diameter (mm): Similar trend of the results was observed pod diameter. The soaking periods and quantis levels as an independent factor had significant effect on pod diameter. However, soaking periods and quantis levels are not interacted significantly with each other. The pod diameter ranges from 11.67 to 38.68 mm produced maximum from 40 ml L^{-1} quantis solution. Control had minimum pod diameter. The pod diameter of okra treated by different quantis levels and soaking time The results further showed that the pod diameter of okra was observed greater (27.43 mm) in response to 24 hours soaking followed by 16 (25.18 mm) and 8 (22.92 mm) hours.

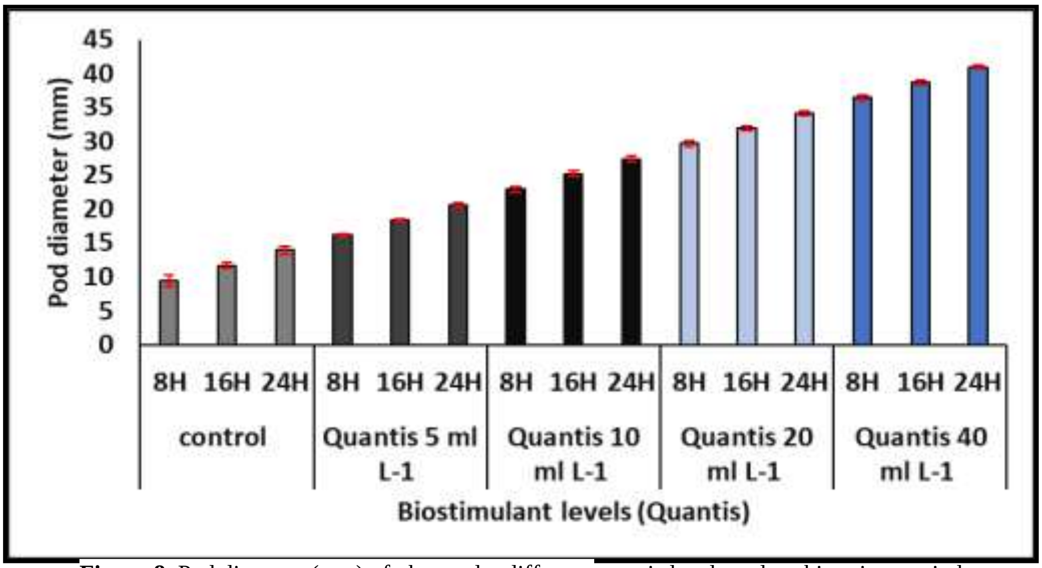

Figure 8. Pod diameter (mm) of okra under different quantis levels and soaking time period

Weight of single pod (g): Weight of single pod had significant differences due to varying quantis levels and soaking time periods (Figure 9). Two factors are involved here but they are not interactively significant with each other. They worked well as an independent factors. To compare weight of single pod on the basis of quantis levels, maximum weight (11.84 g) was noted in response to 40 ml L^{-1} quantis solution followed by 20 ml L^{-1} (10.79 g), 10 ml L^{-1} (9.74 g) and 5 ml L^{-1} (8.90 g). The pod in minimum weight was observed from control (7.95 g). Soaking time had also good response on weight of single pod. 24 hours soaking had greater weight of pods (10.15 g), 16 hours (9.86 g) and 8 hours (9.51 g).

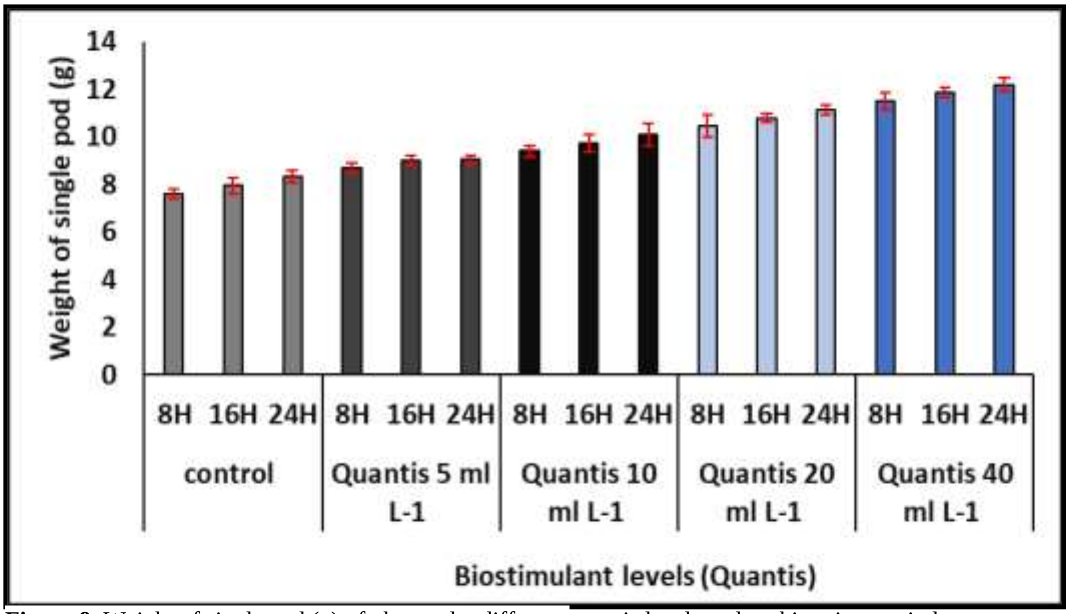

Figure 9. Weight of single pod (g) of okra under different quantis levels and soaking time period

Pod yield plant^{-1}: Pod yield is based on the pod weight and diameter. Pod yield varied significantly due to varying quantis levels and soaking time periods (Figure 10). The treatment 40 ml L^{-1} exhibited maximum pod yield plant^{-1} (325.66 g); significantly followed by 20 ml L^{-1} and 10 ml L^{-1} resulting pod yield plant^{-1} of (283.66 g) and (241.66 g), respectively Soaking of the seeds in quantis solution had also significant effect on pod yield produced maximum pod yield (255.43 g) in response to 24 hours soaking, followed by 16 hours (241.37 g) and 8 hours soaking (227.43 g).

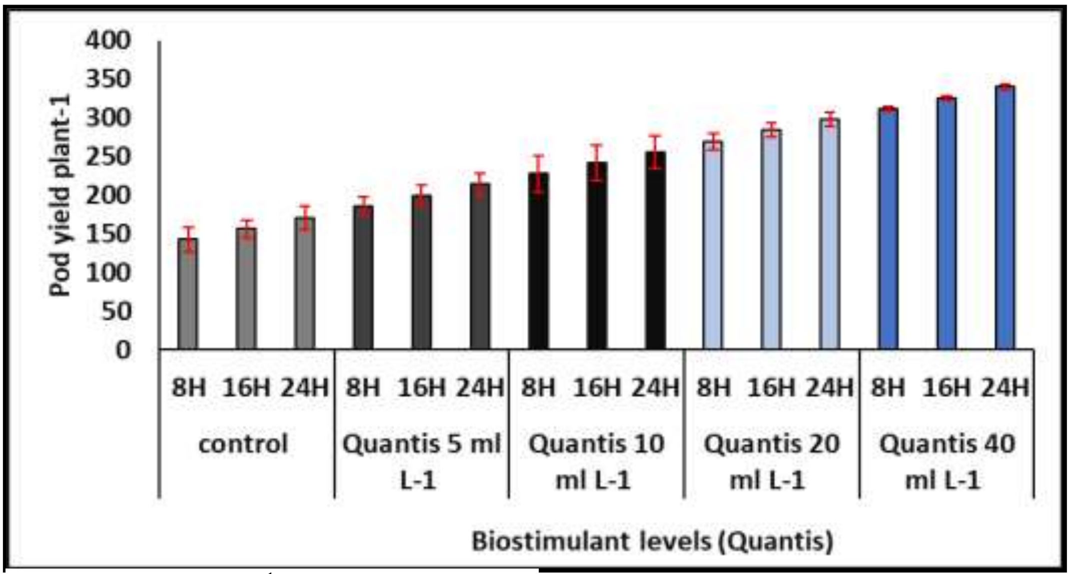

Figure 10. Pod yield plant^{-1} (g) of okra under different quantis levels and soaking time periods

Discussion

In the modern era, plant growth and productivity are threatened by abiotic stress. Abiotic stressors like salinity, drought, and high temperatures cause massive crop losses all over the world (Singh &Takhur. 2018). Application with biostimuant is becoming a novel and sustainable approach towards crop production, especially under biotic and abiotic stressors (Bulgari *et al*., 2014).Biostimulants are the organic substances and microorganisms that regulate plant growth in number of ways (Yakhin *et al*., 2017; Tarantino *et al*., 2018). Application of these compounds during the growth and developmental stages of the crops can promote crop growth and nutrient balance, abiotic stress tolerance, resulting in improved quality and yield (Laane, 2018; Oosten *et al*., 2017). Moreover, biostimulants improve growth of the plants in organic management system. These are available in the market include seaweek, fungi, bacteria, animals, higher plants and humate containing raw material (Ahmad & Pitchtel, 2008).

Growth and yield of okra depends upon many factors like seed quality, nutrition, climatic conditions, and cultural practices (Kusvuran, 2012). In the present study Quantis as a biostimulant was applied as a seed priming agent for different time periods. Application of 40 ml L^{-1} quantis solution exhibited good results for seed germination, vegetative growth, flowering and yield related parameters as compared to control plants. Similar results were observed in okra by different scientists. Different scientists used different biostimulants and the result values may vary. Vishnu and Rao (2018) studied the effects of growth stimulants on morophological and phenolgical parameters of Okra. They reported that the morphological and phenological parameters such as plant height, leaf area per plant, leaves per plant, branches per plant, days to 50% flowering, days to first harvest and duration of crop were significantly influenced by the growth stimulants application. Durand *et al*. (2003) reported that the liquid extract obtained from seaweeds has recently gained much interest as foliar spray for increasing growth and yield in cereal crops, vegetables, fruits, orchards and horticultural plants. The extracts obtained from the marine algae improved the growth and yield of various crops (Turan and Kose, 2004). The combination of bio-stimulant extract of golden apple snails of 20 mL/L water and NPK fertilizer of 150 kg/ha (1 g/polybag) had the highest resulted in the average value of growth and yield of okra on the ultisol soils (Nurshanti *et al*., 2021). Zaman *et al*. (2021) studied that the use of biostimulants had a significant and beneficial effect on plant height, branches per plant, fruits per plant and mineral nutrient contents of okra. They observed plant height increased by an average of 38% as compared to control. These beneficial results of biostimulant in agriculture is related to the presence of active components recognized to have beneficial effects on plant growth (Nardi *et al*., 2016). These macro- and micronutrients include amino acids, vitamins, cytokinins, auxins and abscisic acid (Hernández-Herrera *et al*., 2014). Papenfus *et al*. (2013) reported that seaweed concentrate improve seedlings growth of Okra under nutrient deficiency.

Conclusions

It is concluded from the present study that the seed priming with biostimulant (quantis) had a significant effect on the growth, flowering and yield related parameters. The biostimulant level of 40 ml L^{-1} resulted in the highest average values for plant height, flowering and pod related parameters as pod weight, length, diameter and number of pods per plant. The soaking of the seeds in the biostimulant solution for 24 hours resulted also improved morphological and yield parameters.

Reference

Agudelo-Morales, C.; Tulio, L.; Jina, M.L., Manuel, P. & Enrique C. (2021). Phytohormones and Plant Growth Regulators - A Review. Journal of Science with Technological Applications. **10**, 27-65.

Ahmad, J. & Pichtel, S.H. (2008). Plant-Bacteria interactions: Strategies and techniques to promote plant growth. WILEY-VCH Verlag GmbH and Co, KGaA, Weinheim.

Aliferis, K. A., & Jabaji, S. (2015). Metabolomics–A robust bioanalytical approach for the discovery of the modes-of-action of pesticides: A review. Pesticide Biochemistry and physiology, **100**(2), 105-117.

Anwar, F., Rashid, U., Mahmood, Z., Iqbal, Z. T. & Sherazi, T. H. (2011). Intervarietal variation in the composition of okra (Hibiscus esculentus L.) seed oil. Pakistan Journal of Botany, **43**, 271-280.

Bilal, M. H., & Zubair, M. (2018). Production Technology and Nutritive Value of Okra. Agrihunt.com

Bukhari, U. (2020). Okra cultivation in Pakistan. Gardening with Horticulturist, gardeninig digitalz.com.

Bulgari R., Cocetta G., Trivellini A., Vernieri P. & Ferrante A. (2014). Biostimulants and crop responses: A review. Biological Agriculture & Horticulture, **31**:1–17

Bulgari, R., Franzoni, G., & Ferrante, A. (2019). Biostimulants application in horticultural crops under abiotic stress conditions. Agronomy, **9**(6), 306.

Chittora, A., Singh, N., & Singh, D. K. (2017). Production technology of okra. Marumegh, **1**(1):48-51.

Damalas, C.A., Koutroubas, S.D., Fotiadis, S., Damalas, A., & Koutroubas, D. (2019). Hydro-priming effects on seed germination and field performance of faba bean in spring sowing. Journal of Agriculture, **9**(9),201-212.

Dantas, T.L.; Alonso Buriti, F.C., & Florentino, E.R. (2021). Okra (Abelmoschus esculentus L.) as a Potential Functional Food Source of Mucilage and Bioactive Compounds with Technological Applications and Health Benefits. Plants **10** (8), 1683.

Durand N, Briand, X. & Meyer, C. (2003) The effect of marine bioactive substances (NPRO) and exogenous cytokinins on nitrate reductase activity in Arabidopsis thaliana. Plant Physiology, **119**(4), 489-493.

FAOSTAT, 2023. Food and Agriculture Organization of the United Nations. Available online with updates at: http://www.fao.org

FAOSTAT, 2018. Food and Agricultural Organization, Statistics Division, http: //www.fao.org.

Gemede, H.F., Woldegiorgis, A.Z., Retta, N., & Haki, G.D. (2015). Nutritional quality and health benefits of okra (Abelmoschus esculentus): A review. American Journal of Food Sciences and Nutrition, **6**, 208–215.

González Guzmán, M., Cellini, F., Fotopoulos, V., Balestrini, R. & Arbona, V. (2022). New approaches to improve crop tolerance to biotic and abiotic stresses. Plant Physiology, **174** (1), 13547.

Halpern, M., Bar-Tal, A., Ofek, M., Minz, D., Muller, T., & Yermiyahu, U. (2015). The use of biostimulants for enhancing nutrient uptake. Advances in agronomy, **130**, 141-174.

Hernández-Herrera, R. M., Santacruz-Ruvalcaba, F., Ruiz-López, M. A., Norrie, J., & Hernández-Carmona, G. (2014). Effect of liquid seaweed extracts on growth of tomato seedlings (Solanum lycopersicum L.). Journal of applied phycology, **26**, 619-628.

Jardin, P. D. (2015). Plant biostimulants: Definition, concept, main categories and regulation. Scientia Horticulturae, **196**, 3-14.

Khan, A.S., M.A. Khan, M. Fawad and M. Sadiq. (2022). Utilizing weeds as a source of organic fertilizer for improving okra (Abelmoschus esculentus L.) yield attributes. Pakistan Journal of Weed Science Research, **28**, 447-456.

Khan, M., Ali, S., Ali, N., Aslam, S., Akbar, R., Ansari, M., Fahad, S., Dutta, R., Danish, S., Hassan, S., Nawaz, T. & Saud, S. & Adnan, M. (2023). Response of okra (*Abelmoschus esculentus* L.) F5:6 population of for earliness and yield traits. Pakistan Journal of Botany. **55**(2), 689-695.

Kusvuran S. (2012). Influence of drought stress on growth, ion accumulation and antioxidative enzymes in okra genotypes. International Journal of Agriculture and Biology, **14**, 401-406.

Laane. (2018). The Effects of Foliar Sprays with Different Silicon Compounds. Plants., **7** (2), 45. DOI: 10.3390/plants7020045.

Mrid, R. B., Benmrid, B., Hafsa, J., Boukcim, H., Sobeh, M., & Yasri, A. (2021). Secondary metabolites as biostimulant and bioprotectant agents: A review. Science of The Total Environment, **777**, 146204.

Nardi, S., Pizzeghello, D., Schiavon, M., & Ertani, A. (2016). Plant biostimulants: physiological responses induced by protein hydrolyzed-based products and humic substances in plant metabolism. Scientia Agricola, **73**, 18-23.

Nurshanti, D.F., Defrian, D. & Novrian, N. (2021). Growth and yield of okra applied with a bio-Stimulant from golden apple snails extracts and fertilizer on Ultisol. Jurnal Lahan Suboptimal: Journal of Suboptimal Lands, **10**(1), 37-45.

Oosten, M. J., Pepe, O., De Pascale, S., Silletti, S., & Maggio, A. (2017). The role of biostimulants and bioeffectors as alleviators of abiotic stress in crop plants. Chemical and Biological Technologies in Agriculture, **4**, 1-12.

Papenfus, H.B., Kulkarni, M.G., Stirk, W.A., Finnie, J.F. & Van Staden, J. (2013). Effect of a commercial seaweed extract and polyamides on nutrient-deprived (N, P and K) of okra seedlings. Scientia Horticulturae, **151**:142-146

Rafiee, H., Naghdi Badi, H. A., Mehrafarin, A., Qaderi, A., Zarinpanjeh, N., Sękara, A., & Zand, E. (2016). Application of plant biostimulants as new approach to improve the biological responses of medicinal plants-A critical review. Journal of Medicinal Plants, **15**(59), 6-39.

Sheikh, S. A., Nizamani, S. M., Jamali, A. A., Panhwar, A. A., Channa, M. J., & Mirani, B. N. (2012). Removal of Pesticide Residues from Okra Vegetable through Traditional Processing . *Journal of Basic & Applied Sciences*, **8,** 79–84.

Singh, J., & Takhur, J. K. (2018). Photosynthesis and abiotic stress in plants. Biotic and Abiotic Stress Tolerance in Plants. Singapore: Springer Nature Singapore Private Ltd, 27-46.

Statistix. (2006). Statistics 8.1 user guide, version 1.0. Analytical software, P.O. Box 12185, Tallahassee fl 32317 USA.

Tarantino, A., Lops, F., Disciglio, G., & Lopriore, G. (2018). Effects of plant biostimulants on fruit set, growth, yield and fruit quality attributes of 'Orange rubis®'apricot (Prunus armeniaca L.) cultivar in two consecutive years. Scientia Horticulturae, **239**, 26-34.

Turan, M., & Köse, C. (2004). Seaweed extracts improve copper uptake of grapevine. Acta Agriculturae Scandinavica, Section B-Soil & Plant Science, **54**(4), 213-220.

Uwiringiyimana, T., Habimana, S., Umuhozariho, M. G., Bigirimana, V. P., Uwamahoro, F., Ndereyimana, A., & Naramabuye, F. X. (2024). Review on Okra (Abelmoschus esculentus (L.) Moench) Production, Nutrition and Health Benefits. Rwanda Journal of Agricultural Sciences, **3**(1), 71-87.

Vishnu, K.S. and Rao, S.G.V. (2018). Effect of Growth Stimulants on Morphological and Phenological Parameters of Okra (Abelmoschus esculentus L.) cv. Arka Anamika under Soil test Based Nutrient Management System. International Journal of current microbiology and applied sciences, **7** (08):1658-1665.

Yakhin, O. I., Lubyanov, A. A., Yakhin, I. A., & Brown, P. H. (2017). Biostimulants in plant science: a global perspective. Journal of Frontiers in Plant Science, **7**, 249-262.

Yaronskaya, E., Vershilovskaya, I., Poers,Y., Alawady, A.E., Averina, N. & Grimm, B. (2006). Cytokinin effects on tetrapyrrole biosynthesis and photosynthetic activity in barley seedlings. Planta, **224**,700-709

Zamana S, Sokolov A, Fedorovskiy T, Sokolov S, Kondratyeva T. (2021). Efficacy of application of biostimulants based on non-pathogenic microorganisms when growing okra in Arkansas. Journal of Biomedical Research & Environmental Sciences, **2**, 218-222.