

<http://www.pjbs.org>

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSI*net*

Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Research Article

Optimizing Biosaka Elicitor Concentration for Enhanced Growth and Yield of Cherry Tomato (*Solanum lycopersicum* L. var. *cerasiforme*)

Elimasni Elimasni and Sayyidah Afinah Salsabila Nasution

Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, Kota Medan, Indonesia

Abstract

Background and Objective: Prolonged utilization of chemical fertilizers can harm the soil and disturb the equilibrium of nutrients, resulting in a decline in cherry tomato yield. To enhance the growth of cherry tomato plants, it is necessary to add organic chemicals. The research aimed to determine the best elicitor biosaka concentration to apply to evoke the plant growth of cherry tomatoes (*Solanum lycopersicum* L. var. *cerasiforme*). **Materials and Methods:** This study employed a complete random design with four treatments of biosaka formula: B0 (control, water), B1 (1.5 mL/L), B2 (2.5 mL/L), B3 (3.5 mL/L) and B4 (4.5 mL/L). Twenty-day-old tomato seedlings were transplanted into polybags filled with a compost and husk charcoal mixture. Biosaka application was done every four days by spraying at a 0.5 m distance, starting from the first day after transplanting. Lycopene levels were measured using a UV-vis spectrophotometer at 417 nm after a series of solvent extractions. Data were analyzed using ANOVA for significant effects. **Results:** The biosaka concentration of 4.5 mL/L gives the highest results for the variables of treatments such as the plant height is up to 167.8 cm, the number of petioles is 62.8 petioles, the number of fruit is 19.6 and the age at flowering is 44.4 days. The biosaka concentration of 4.5 mL/L gave the highest yield for the variable plant height of 167.8 cm, the number of petioles 62.8, the number of fruits per plant 19.6, the initial flowering age of 44.4 days, the wet weight of the plant was 740 g and the dry weight of the plant was 125.1 g. **Conclusion:** The optimal concentration of biosaka (4.5 mL/L) significantly improved cherry tomato growth and yield, resulting in increased plant height, number of petioles and fruit count. It also accelerated the initial flowering age and enhanced both wet and dry plant weights. This indicates that 4.5 mL/L of biosaka effectively promotes the growth and productivity of cherry tomato plants.

Key words: Biosaka elicitor, growth enhancement, yield optimization, plant height, flowering age, organic fertilizer

Citation: Elimasni, E. and S.A.S. Nasution, 2024. Optimizing biosaka elicitor concentration for enhanced growth and yield of cherry tomato (*Solanum lycopersicum* L. var. *cerasiforme*). Pak. J. Biol. Sci., 27: 577-586.

Corresponding Author: Elimasni Elimasni, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, Kota Medan, Indonesia

Copyright: © 2024 Elimasni Elimasni and Sayyidah Afinah Salsabila Nasution. This is an open access article distributed under the terms of the creative commons attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cherry tomatoes are commonly cultivated by farmers using chemical fertilizers and pesticides due to their practicality and rapid results¹. However, prolonged use of these chemicals can damage agricultural land, disrupt nutrient balance and reduce the resilience of plants to pests and diseases². This can ultimately lead to a decline in tomato production. To counteract these negative effects and improve cherry tomato productivity, the addition of organic compounds is essential. One promising organic alternative is biosaka, an innovative agricultural technology that helps reduce the reliance on chemical inputs³. Biosaka is derived from various weeds and grasses, which can protect plants from diseases and pests while reducing the use of inorganic fertilizers by 50-90%. Commonly used weeds in biosaka include *Ageratum conyzoides*, *Elephantopus mollis*, *Hippobroma longiflora*, *Cleome rutidosperma* and *Euphorbia hirta*, all of which have high vegetative reproductive power and are readily available in nature. These weeds contain beneficial chemical compounds such as terpenoids, phenols and flavonoids, which serve as natural defenses against pathogens and function as growth regulators⁴.

The weeds used in this study consist of 5 types of plants that are easy to find in nature and have high vegetative reproductive power. Weeds show potential as a source of organic matter⁴. The chemical content in weeds such as terpenoids, phenols and flavonoids has the ability to defend against pathogens and growth regulators⁵.

Biosaka active ingredients contain phytohormones in the form of auxin, gibberellin and cytokinin which are effective in spurring plant growth, flowering and fruiting. Macronutrients found in biosaka solutions include nitrogen (N), phosphate (P), carbon (C) and potassium (K) which are needed by plants in the metabolic process⁶. Plant Growth Promoting Rhizobacteria (PGPR) also found in biosaka is a group of beneficial bacteria that have a positive effect on plant growth⁷. Types of bacteria in PGPR such as *Bacillus subtilis* and *Rhizobium* sp., capable of producing toxins to fight pathogenic fungi⁸. These positive bacteria also act as biostimulants because they can produce plant hormones, dissolve phosphate and fix nitrogen from the air.

This study aims to evaluate the optimal concentration of biosaka to enhance the growth and yield of cherry tomato plants (*Solanum lycopersicum* L. var. *cerasiforme*). By determining the most effective biosaka concentration, the research seeks to promote sustainable agricultural practices and improve the overall productivity of cherry tomato cultivation.

MATERIALS AND METHODS

Study area: The study was carried out from December, 2023 to April, 2024. The research was conducted at Rumah Kasa, Faculty of Agriculture and Laboratory of Plant Physiology and Tissue Culture, Department of Biology, Faculty of Mathematics and Science, Universitas Sumatera Utara, Indonesia.

Complete random design of biosaka formulas: This study is an experimental study using a Complete Random Design (CDR), which is a biosaka formula consisting of 4 different treatments:

- **B0:** Water (control)
- **B1:** 1.5 mL/L water
- **B2:** 2.5 mL/L water
- **B3:** 3.5 mL/L water
- **B4:** 4.5 mL/L water

Composition and manufacturing of biosaka: Babadotan (*Ageratum conyzoides* L.), patikan kebo (*Euphorbia hirta* L.), meniran (*Phyllanthus niruri* L.), jelantir (*Erigeron sumatrensis* Retz), sembung rambat (*Eupatorium denticulatum* Vahl) washed first (Table 1). The weeds (tomato seeds were obtained from Malang, East Java with SKU No. 7717990618_ID-14209082518) are squeezed gently twisting to the left and interspersed with mixing. Each weed obtained is weighed as much as 60 g. Squeeze is carried out for about 10-15 min until the weeds are crushed and the juices come out. Finishing is stopped when the color has a homogeneous dark brown and is slightly foamy. Biosaka can be applied directly with the addition of clean water. Biosaka was obtained from 300 g of weeds, which is about ± 20 mL and homogeneity testing was carried out with a TDS tool until it showed a concentration of 510 ppm.

Biosaka application: Tomato seedlings (tomatoes grown in screen house, faculty of agriculture, USU) are already 20 days old and are transferred into polybags that have been filled with a mixture of compost and husk charcoal. The planting hole is 5 cm deep. Transplantation is carried out carefully to keep the roots of the plant from being damaged or broken. Seedlings are watered first to avoid stress, then watering is done 1 time a day. Biosaka application is carried out every 4 days, starting from the first day after planting, with a spray distance of 0.5 m. The initial spraying is carried out once (0.5 mL of biosaka), then the spraying volume is increased as the age of the plant increases. The application is carried out during the plant's vegetative growth and is stopped after the plant has flowered.

Table 1: Chemical composition and characteristics of weeds used in biosaka formulation

Types of weeds	Weight (g)	Percentage	Compounds
Patikan kebo (<i>Euphorbia hirta</i>)	60	20	Flavonoids, tannins, triterpenoids, glycosides, saponins, ascorbic acid, euphorbin, beta-sitosterol, kaempferol, gallic acid and water level 13,58% ⁹
Babadotan (<i>Ageratum conyzoides</i>)	60	20	Flavonoids, saponins, polyphenols, coumarine, eugenol 5%, essential oils, water level 15% and sulfur ¹⁰
Jelantir (<i>Erigeron sumatrensis</i>)	60	20	Flavonoids, tannins, triterpenoids, steroids, saponins, glycosides, beta fersene and anthraquinones ¹¹
Meniran (<i>Phyllanthus niruri</i>)	60	20	Flavonoids, polyphenols, saponins, quinones, potassium salts, lignin, peptides, vitamin C, hypophyllantine, auxin hormones, endophytic fungi (<i>Aspergillus</i> sp.) and cellulase enzymes ¹²
Sembung rambat (<i>Eupatorium denticulatum</i>)	60	20	Flavonoids, steroids, tannins, alkaloids, terpenoids, saponins and phenols ¹³
Total	300	100	

Harvesting cherry tomato plants: Cherry tomatoes can be harvested when they are 8-12 weeks old. Harvesting activities are carried out in the morning, this aims to reduce evaporation. Harvesting can be done by picking cherry tomatoes that are red or yellow-orange, picking them slowly so that the tomatoes that are still green do not detach from the stalk and do not cause losses.

Testing of lycopene levels of cherry tomatoes: A total of 50 g of cherry tomatoes were weighed and then blended for each treatment and filtered using a sieve. The tomato filter water is filtered again using filter paper until yellow-colored water (tomato water) is obtained¹⁴. During the process, the tomato filter water is placed in an Erlenmeyer flask which is covered on the outside with aluminum foil. Lycopene levels were tested by taking a 5 mL sample from the non-polar layer formed in the tomato juice above and placing it in a 100 mL beaker covered with aluminum foil. A total of 5 mL of the tomato sample was dissolved in 50 mL of a combination of hexane, acetone and ethanol solvents with a ratio of 2:1:1 v/v and shaken with a magnetic stirrer for 30 min. The solution was transferred to a separating funnel, then 10 mL of distilled water was added and shaken again with a magnetic stirrer for 15 min. The upper part is taken and separated by opening the bottom of the funnel so that the polar layer is removed, organic solvent is added up to the limit mark. Determination of lycopene levels was measured using a UV-Vis spectrophotometer (Shimadzu 1240, Japan 2016) with a wavelength of 417 nm.

Observation variables: In this study, the parameters observed are as follows.

Plant height (cm): The height of the plant is measured using a meter or ruler. Plants are measured from the base of the stem to the tip of the leaf. Observations were made on 14, 35, 56 and 77 HST.

Number of petioles (stalks): The calculation of the number of leaf stalks was carried out at 14, 35, 56 and 77 HST.

Number of planted fruits (fruits): The fruits harvested for counting are tomatoes that are red, orange and green in uniform size.

Early flowering age (days): The beginning of flowering is observed and then the date of the beginning of the appearance of the flowers in each treatment is recorded.

Wet weight of cherry tomato plants (g): The wet weight is calculated by weighing sample plants after harvest without going through the drying process first.

Dry weight of cherry tomato plants (g): The dry weight of the plants is baked at a temperature of 105°C for 24 hrs, until the lost moisture content is around $\pm 75\%$ and then calculated by weighing the plants after being ovened.

Lycopene level test of cherry tomatoes (mg/100 mL): Lycopene levels are calculated using the formula¹⁵:

$$C = \frac{A}{E_{1\text{cm}}^{1\%} \times b}$$

Where:

C = Concentration (mg/100 mL)

A = Absorbance

b = Thick of cuvettes (cm)

$E_{1\text{cm}}^{1\%} = 3.450$

Data analysis: The data collected were analyzed utilizing SPSS version 22 software, employing the Analysis of Variance (ANOVA) test with a $p < 0.05$. If the treatment has a significant effect, it will proceed with the Duncan's New Multiple Range Test (DNMRT).

RESULTS

Plant height (cm): The observation of the height of cherry tomato plants was shown in Fig. 1. It can be seen that the observations on day 35, 56 and 77 HST show a noticeable increase, except for the observation at 14 HST.

Figure 1a shows that each treatment experienced an increase in height for each measurement. Observations at 14 HST, the plants had not shown significant growth because the plants were still in the process of adapting from the seedling media to the growing polybags and the amount of biosaka given was still small. This means that the effects of

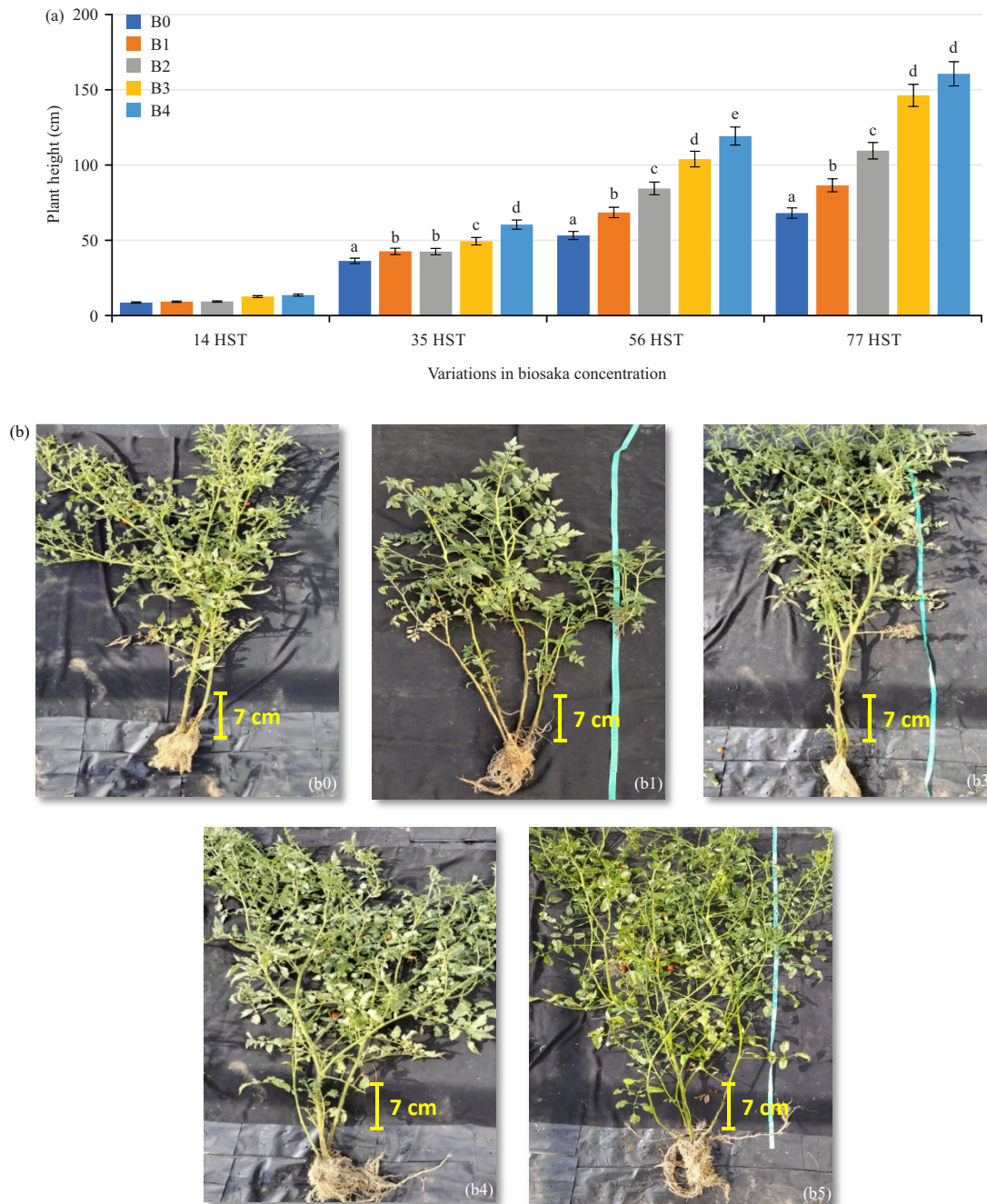


Fig. 1(a-b): (a) Plant height (cm) of cherry tomato (*Solanum lycopersicum* L. var. *cerasiforme*) with biosaka concentration variation treatment and (b) Comparison of cherry tomato plant height at 77 DAP

Cherry tomato height with treatment B0: Control, B1: 1.5 mL/L of water, B2: 2.5 mL/L of water, B3: 3.5 mL/L of water, B4: 4.5 mL/L of water and different letters indicate significant differences (p < 0.05)

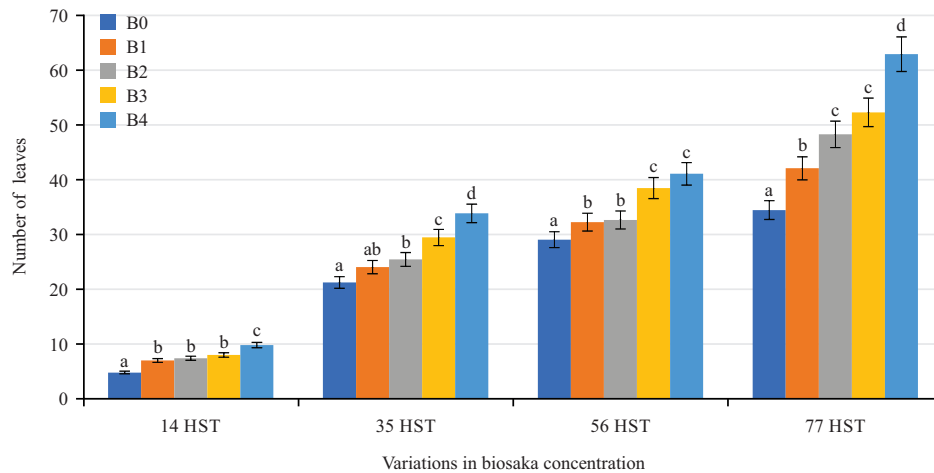


Fig. 2: Number of petioles of cherry tomatoes (*Solanum lycopersicum* L. var. *cerasiforme*) with biosaka concentration variation treatment

B0: Control, B1: 1.5 mL/L water, B2: 2.5 mL/L water, B3: 3.5 mL/L water, B4: 4.5 mL/L water and different letters indicate significant differences ($p < 0.05$)

biosaka are not yet visible. Plants will experience stress after transplanting because the plants are still adapting to the formation of new roots. The height of cherry tomato plants at 35, 56 and 77 HST showed significant differences. Giving biosaka with a concentration of 4.5 mL/L water (B4) showed the highest results in each observation. The higher the concentration of biosaka given, the greater the nutrients obtained by the plant.

Plant height increased across the board for all treatments, as seen in Fig. 1b. Due to the plants' ongoing adaptation from seedling medium to the expansion polybag and the relatively small amount of biosacka provided, observation 14 HST shows that the plants have not shown substantial growth. Because of this, the benefits of taking biosaka will go unnoticed. After a transplant, plants will go through a period of stress as they adjust to their new root system. The ability of plants to adapt and absorb nutrients effectively is demonstrated by the development of new leaves and the elongation of stems. At 35, 56 and 77 HST, there is a noticeable difference in the height of cherry tomato plants. The plants' slow growth is shown in Fig. 1a (B0) compared to Fig. 1b (B1). Figure 1c (B2) and 1d (B3) show the first signs of growth. Biosaka at a concentration of 4.5 mL/L in water (B4) produced the best results across the board (Fig. 1e). Plants are believed to benefit from higher concentrations of biosacca because of the favorable relationship between the two variables.

Number of leaves: The observation of the number of leaves was shown in Fig. 2. It can be seen that the application of

biosaka significantly increases the number of leaves for each observation day.

Figure 2 shows that the number of cherry tomato leaves given a concentration of 4.5 mL/L water (B4) showed the highest results in each observation. Similar to the results of observing plant height, biosaka also plays a role in increasing the number of leaves. The observations obtained show that the effect of giving higher concentrations of biosaka can accelerate plant growth and production, whereas using lower concentrations can slow down plant growth and productivity is not optimal. The low growth and yield of plants at a concentration of 1.5 mL/L water (B1) is thought to be because the available nutrients cannot meet the needs for vegetative growth, thus affecting the number of plant leaves.

Early flowering age (days): The generative phase of the plant is characterized by the appearance of flowers. The beginning of the flowering of cherry tomatoes was shown in Fig. 3. It can be seen that the application of biosaka has a noticeable influence on the flowering lifespan.

In Fig. 3, it can be known that the increase in biosaka concentration causes an acceleration of the early flowering age of cherry tomatoes. The earliest flowering age of cherry tomatoes was 44.4 days obtained at a concentration of 4.5 mL/L compared to the control of 55.4 days. This is because the higher the concentration of biosaka given, the available nutrients also increase. Based on the results of the analysis of biospace nutrient content, it contains 2.38% of element K and 2.05% of element P.

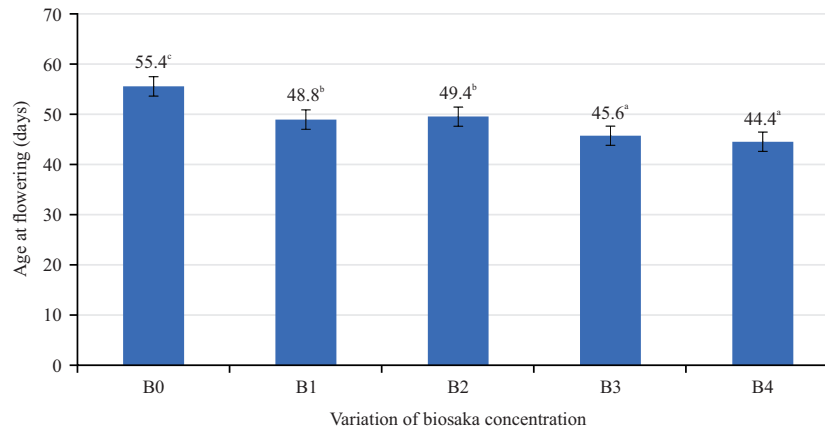


Fig. 3: Early flowering age (days) of cherry tomatoes (*Solanum lycopersicum* L. var. *cerasiforme*) with biosaka concentration variation treatment

B0: Control, B1: 1.5 mL/L water, B2: 2.5 mL/L water, B3: 3.5 mL/L water, B4: 4.5 mL/L water and different letters indicate significant differences ($p < 0.05$)

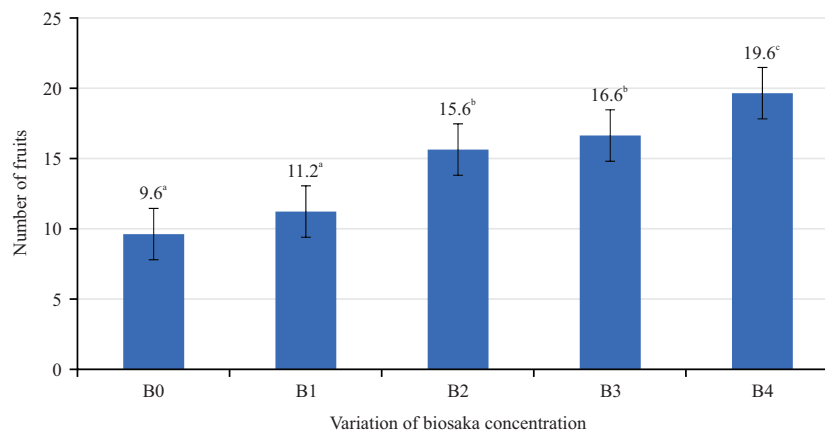


Fig. 4: Number of fruits of cherry tomato cultivation (*Solanum lycopersicum* L. var. *cerasiforme*) with biosaka concentration variation treatment

B0: Control, B1: 1.5 mL/L water, B2: 2.5 mL/L water, B3: 3.5 mL/L water, B4: 4.5 mL/L water and different letters indicate significant differences ($p < 0.05$)

Number of fruits planted (fruit): Observation of the number of cultivated fruits shows a significant increase in line with the addition of biosaka concentration, the complete data is shown in Fig. 4.

Figure 4 showed that the increase in biosaka concentration had an effect on the increase in the number of cherry tomatoes planted. The concentration of 4.5 mL/L of water (B4) gave the highest number of cherry tomatoes which was 19.6 and significantly different from the control which was 9.6 pieces. The increase in fruit is caused by the increasing concentration of biosaka, which has a positive effect on the number of fruits planted.

Plant wet weight (g): The wet weight of the plants also showed a marked increase in line with the increase in biospace concentration, the full data of which is shown in Fig. 5.

Figure 5 shows that the wet weight of the plants increases as the biosaka concentration increases. Biosaka with a concentration of 4.5 mL/L (B4) showed the highest wet weight yield of 740 g compared to other treatments.

Dry weight of plants (g): Dry weight of plants has also increased significantly with the addition of biosaka concentrations, full data was shown in Fig. 6.

Figure 6 shows that the increase in biosaka concentration leads to an increase in the wet weight of cherry tomato plants along with biosaka feeding. Biosaka with a concentration of 4.5 mL/L of water (B4) produced the highest dry weight with an average value of 125.1 g. The higher the concentration of biosaka given, the higher the vegetative growth will result.

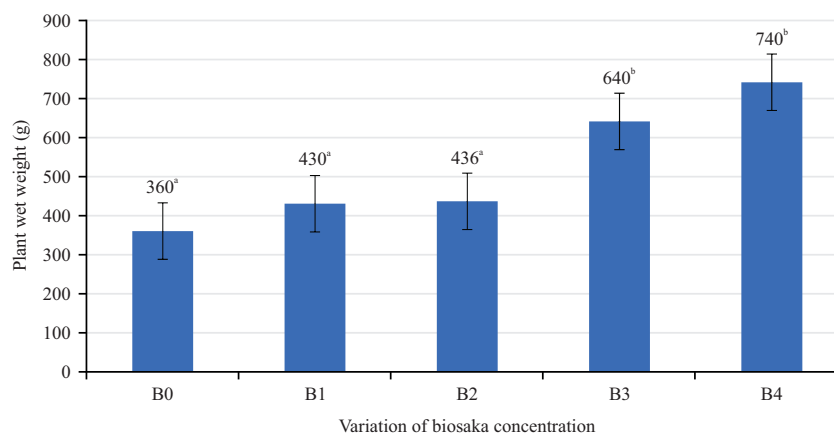


Fig. 5: Wet weight of cherry tomato plants (*Solanum lycopersicum* L. var. *cerasiforme*) with biosaka concentration variation treatment

B0: Control, B1: 1.5 mL/L water, B2: 2.5 mL/L water, B3: 3.5 mL/L water, B4: 4.5 mL/L water and different letters indicate significant differences ($p < 0.05$)

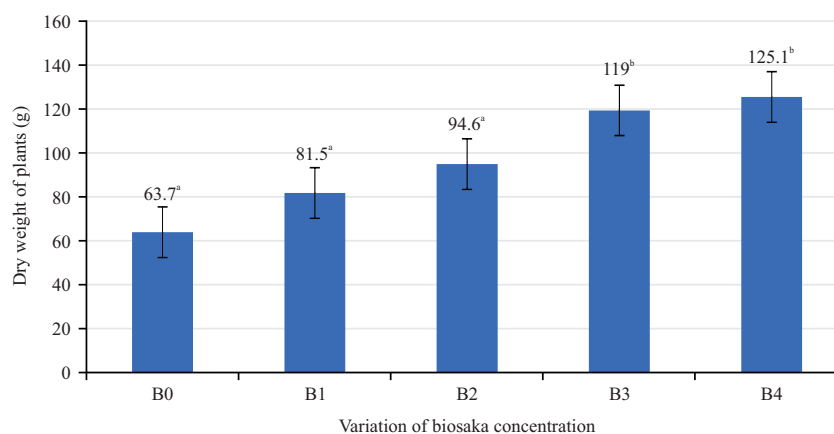


Fig. 6: Dry weight of cherry tomatoes (*Solanum lycopersicum* L. var. *cerasiforme*) with biosaka concentration variation treatment

B0: Control, B1: 1.5 mL/L water, B2: 2.5 mL/L water, B3: 3.5 mL/L water, B4: 4.5 mL/L water and different letters indicate significant differences ($p < 0.05$)

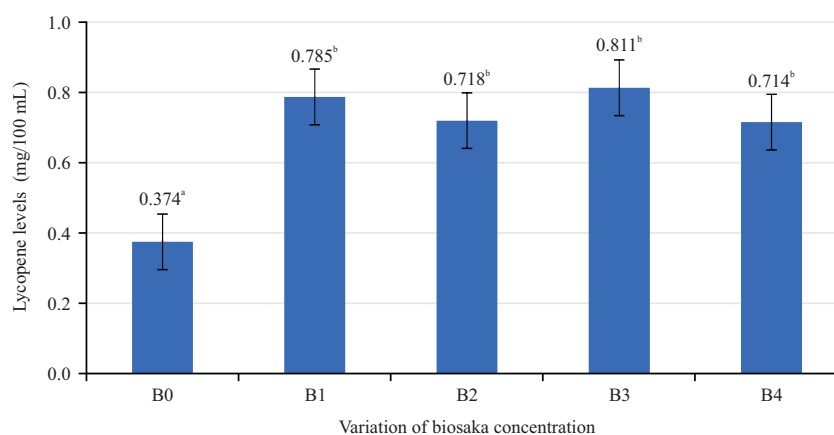


Fig. 7: Lycopene levels of cherry tomatoes (*Solanum lycopersicum* L. var. *cerasiforme*) with biosaka concentration variation treatment

B0: Control, B1: 1.5 mL/L water, B2: 2.5 mL/L water, B3: 3.5 mL/L water, B4: 4.5 mL/L water and different letters indicate significant differences ($p < 0.05$)

Lycopene levels of cherry tomatoes (mg/100 mL): The synthesis of lycopene pigment is in line with the color level on the surface of the tomato. The high and low levels of lycopene indicate the color index in tomatoes related to the level of ripeness. The results of the statistical analysis of the lycopene level test of cherry tomatoes can be seen in Fig. 7.

Figure 7 shows that biosaka administration at concentrations of 1.5-4.5 mL/L significantly increases lycopene levels when compared to controls. This is because, during the ripening process, the fruit undergoes several biochemical and physiological changes that change its bioactive composition after being sprayed with biosaka.

DISCUSSION

Figure 1 shows that each treatment experienced an increase in height for each measurement. The higher the concentration of biosaka given, the greater the nutrients obtained by the plant. Plant vegetative growth is influenced by the nutrient content contained in the plant¹⁶. Biosaka contains the nutrients nitrogen, phosphorus and potassium in quite high amounts. The N, P and K are important factors and must always be available to plants because they play a role in metabolic processes and cell biochemistry¹⁷. The increasing intensity and volume of biosaka spraying causes nutrients to be absorbed by plants in high concentrations so that the number of leaves formed increases¹⁸. The development of plant tissue is greatly influenced by macro and micro nutrients. The addition of nitrogen elements to plants can encourage the growth of organs related to photosynthesis such as leaves¹⁹. Plants that receive an adequate supply of nitrogen will form dense stalks to support vegetative growth so that the plants are able to produce leaves in large quantities²⁰. The observations obtained show that the effect of giving higher concentrations of biosaka can accelerate plant growth and production, whereas using lower concentrations can slow down plant growth and productivity is not optimal. The low growth and yield of plants at a concentration of 1.5 mL/L water (B1) is thought to be because the available nutrients cannot meet the needs for vegetative growth, thus affecting the number of plant leaves.

Based on the results of the analysis of biospace nutrient content, it contains 2.38% of element K and 2.05% of element P. Element K functions as an activator of various enzymes in photosynthesis and respiration reactions, regulating cell osmotic potential and regulates cell turgor pressure²¹. The element phosphorus plays a role in the process of respiration, photosynthesis and metabolism in plants so that it can increase the process of forming yields and accelerate the

harvest life²². The availability of element K is needed by plants in fruit formation also increases along with the high concentration given²³. Cherry tomatoes applied with higher concentrations of biosaka have a greater wet weight, as essential elements such as nitrogen, phosphorus and potassium that are needed for plant growth and development are more widely available²⁴. Increased nutrient uptake can help plants accumulate more nutrients to produce greater weight. These nutrients can be used by plants to improve the efficiency of photosynthesis, which is the process when plants produce energy from sunlight and convert it into sugar²⁵. The higher the concentration of biosaka given, the higher the vegetative growth will result. This is because the application of biosaka affects the growth phase of cherry tomatoes in the previous parameter²⁶. Factors such as plant height and the total number of photosynthesizing leaves have a significant impact on a plant's weight²⁷. When there are more leaves, photosynthesis works better. Plants will have more energy to grow and develop thanks to the high-energy process of photosynthesis. The amount of leaves has a favorable effect on the plant's dry weight²⁸. The biosaka administration at concentrations of 1.5 to 4.5 mL/L significantly increases lycopene levels when compared to controls. Increases in light intensity, temperature, leaching and shading all contribute to the permeability of the tomato fruit's protective layer, which in turn causes the fruit to collect more lycopene²⁹. This is because, during the ripening process, the fruit undergoes several biochemical and physiological changes that change its bioactive composition after being sprayed with biosaka³⁰. Plants accumulate secondary metabolites, one of which is lycopene as a result of exposure to various stressors or signaling molecules³¹. This can stimulate increased regulation of secondary metabolite synthesis in plants.

CONCLUSION

Biosaka has a notable impact on various aspects of cherry tomato plants (*Solanum lycopersicum* L. var. *cerasiforme*), including plant height, number of flower stalks, early flowering age, number of fruits and wet and dry weight. The study demonstrated that biosaka significantly enhances the growth and yield of cherry tomato plants, influencing variables such as plant height, number of flower stalks, early flowering age and overall plant weight. However, it did not significantly impact the lycopene content in the tomatoes. Future research should explore the effects of different biosaka formulations or combinations with other organic inputs to further optimize lycopene content and overall fruit quality. Additionally, studies could investigate the long-term impacts of biosaka on soil health and sustainability in tomato cultivation.

SIGNIFICANCE STATEMENT

This study discovers that biosaka elicitor increased plant height, number of petioles, number of plant fruits, early flowering age, wet weight, dry weight and had no effect on the lycopene content of cherry tomatoes. The study will help the researcher uncover the role of biosaka elicitor of other plants. Thus, a new theory on the role of biosaka elicitors in agriculture may be arrived at.

REFERENCES

- Guo, X.X., D. Zhao, M.H. Zhuang, C. Wang and F.S. Zhang, 2021. Fertilizer and pesticide reduction in cherry tomato production to achieve multiple environmental benefits in Guangxi, China. *Sci. Total Environ.*, Vol. 793. 10.1016/j.scitotenv.2021.148527.
- Krasilnikov, P., M.A. Taboada and Amanullah, 2022. Fertilizer use, soil health and agricultural sustainability. *Agriculture*, Vol. 12. 10.3390/agriculture12040462.
- Durán-Lara, E.F., A. Valderrama and A. Marican, 2020. Natural organic compounds for application in organic farming. *Agriculture*, Vol. 10. 10.3390/agriculture10020041.
- Valdes, Y.B., 2016. Review: The role of weeds as a component of biodiversity in agroecosystems. *Trop. Crops*, 37: 34-56.
- Al-Khayri, J.M., R. Rashmi, V. Toppo, P.B. Chole and A. Banadka *et al.*, 2023. Plant secondary metabolites: The weapons for biotic stress management. *Metabolites*, Vol. 13. 10.3390/metabo13060716.
- Mukherjee, A., A.K. Gaurav, S. Singh, S. Yadav, S. Bhowmick, S. Abeyasinghe and J.P. Verma, 2022. The bioactive potential of phytohormones: A review. *Biotechnol. Rep.*, Vol. 35. 10.1016/j.btre.2022.e00748.
- de Andrade, L.A., C.H.B. Santos, E.T. Frezarin, L.R. Sales and E.C. Rigobelo, 2023. Plant growth-promoting rhizobacteria for sustainable agricultural production. *Microorganisms*, Vol. 11. 10.3390/microorganisms11041088.
- Saeed, Q., W. Xiukang, F.U. Haider, J. Kučerik and M.Z. Mumtaz *et al.*, 2021. Rhizosphere bacteria in plant growth promotion, biocontrol, and bioremediation of contaminated sites: A comprehensive review of effects and mechanisms. *Int. J. Mol. Sci.*, Vol. 22. 10.3390/ijms221910529.
- Kumar, S., R. Malhotra and D. Kumar, 2010. *Euphorbia hirta*: Its chemistry, traditional and medicinal uses, and pharmacological activities. *Pharmacogn. Rev.*, 4: 58-61.
- Yadav, N., S.A. Ganie, B. Singh, A.K. Chhillar and S.S. Yadav, 2019. Phytochemical constituents and ethnopharmacological properties of *Ageratum conyzoides* L. *Phyther. Res.*, 33: 2163-2178.
- Vladimirov, V., V. Matevski, S. Bancheva, M. Delcheva, M. Kostadinovski and R. Čušterevska, 2016. First report of *Erigeron sumatrensis* (Asteraceae) for the flora of the Republic of Macedonia. *Flora Mediterr.*, 26: 203-207.
- Nisar, M.F., J. He, A. Ahmed, Y. Yang, M. Li and C. Wan, 2018. Chemical components and biological activities of the genus *Phyllanthus*: A review of the recent literature. *Molecules*, Vol. 23. 10.3390/molecules23102567.
- Dev, U.K., M.T. Hossain and M.Z. Islam, 2015. Phytochemical investigation, antioxidant activity and antihelmintic activity of *Mikania micrantha* leaves. *World J. Pharm. Res.*, 4: 121-133.
- Kanski, L., M. Naumann and E. Pawelzik, 2020. Flavor-related quality attributes of ripe tomatoes are not significantly affected under two common household conditions. *Front. Plant Sci.*, Vol. 11. 10.3389/fpls.2020.00472.
- Rodriguez-Amaya, D.B., M. Kimura, IFPRI and CIAT, 2004. HarvestPlus Handbook for Carotenoid Analysis. International Food Policy Research Institute (IFPRI), International Center for Tropical Agriculture, Washington, DC, United States, Pages: 58.
- Akbar, M.A., Khairunnisa, C.S. Meutiasari, M.T. Sari and S.R. Mahyuny, 2024. The influence of Biosaka as an Elisor to increase productivity of food crops Pakcoy (*Brassica rapa* L.) as eco-friendly agricultural innovation. *J. Biologi Tropis*, 24: 821-826.
- Khan, F., A.B. Siddique, S. Shabala, M. Zhou and C. Zhao, 2023. Phosphorus plays key roles in regulating plants' physiological responses to abiotic stresses. *Plants*, Vol. 12. 10.3390/plants12152861.
- Fauzi, D.A., S. Isnaeni and S. Nurhidayah, 2024. The influence of nutrient concentration and hydroponic growing media on the growth and yield of pagoda mustard greens (*Brassica narinosa* L.). *Indones. J. Agron.*, 52: 122-129.
- Fathi, A., 2022. Role of nitrogen (N) in plant growth, photosynthesis pigments, and N use efficiency: A review. *Agrisost*, Vol. 28. 10.5281/zenodo.7438164.
- Anten, N.P.R., 2005. Optimal photosynthetic characteristics of individual plants in vegetation stands and implications for species coexistence. *Ann. Bot.*, 95: 495-506.
- Hasanuzzaman, M., M.H.M.B. Bhuyan, K. Nahar, M.S. Hossain and J. Al Mahmud *et al.*, 2018. Potassium: A vital regulator of plant responses and tolerance to abiotic stresses. *Agronomy*, Vol. 8. 10.3390/agronomy8030031.
- Kumari, V.V., P. Banerjee, V.C. Verma, S. Sukumaran and M.A.S. Chandran *et al.*, 2022. Plant nutrition: An effective way to alleviate abiotic stress in agricultural crops. *Int. J. Mol. Sci.*, Vol. 23. 10.3390/ijms23158519.
- Zhao, W., K. Wu, Y. Wu, H. Yu, W. Cao and H. Ma, 2024. Effects of biochar amendment on greenhouse tomato quality, nutrient uptake and use efficiency under various irrigation and fertilization regimes. *Sci. Hortic.*, Vol. 337. 10.1016/j.scienta.2024.113441.

24. Ddamulira, G., R. Idd, S. Namazzi, F. Kalali, J. Mundingotto and M. Maphosa, 2019. Nitrogen and potassium fertilizers increase cherry tomato height and yield. *J. Agric. Sci.*, 11: 48-55.
25. Bindraban, P.S., C. Dimkpa, L. Nagarajan, A. Roy and R. Rabbinge, 2015. Revisiting fertilisers and fertilisation strategies for improved nutrient uptake by plants. *Biol. Fertil. Soils*, 51: 897-911.
26. Jerca, I.O., S.M. Cîmpeanu, R.I. Teodorescu, E.M. Drăghici, O.A. Nițu, S. Sannan and A. Arshad, 2024. A comprehensive assessment of the morphological development of inflorescence, yield potential, and growth attributes of summer-grown, greenhouse cherry tomatoes. *Agronomy*, Vol. 14. 10.3390/agronomy14030556.
27. Maylani, E.D., R. Yuniati and W. Wardhana, 2020. The effect of leaf surface character on the ability of water hyacinth, *Eichhornia crassipes* (Mart.) Solms. to transpire water. *IOP Conf. Ser.: Mater. Sci. Eng.*, Vol. 902. 10.1088/1757-899X/902/1/012070.
28. Moore, C.E., K. Meacham-Hensold, P. Lemonnier, R.A. Slattery and C. Benjamin *et al.*, 2021. The effect of increasing temperature on crop photosynthesis: From enzymes to ecosystems. *J. Exp. Bot.*, 72: 2822-2844.
29. Jarquín-Enríquez, L., E.M. Mercado-Silva, J.L. Maldonado and J. Lopez-Baltazar, 2013. Lycopene content and color index of tomatoes are affected by the greenhouse cover. *Sci. Hortic.*, 155: 43-48.
30. Gundewadi, G., V.R. Reddy and B.B. Bhimappa, 2018. Physiological and biochemical basis of fruit development and ripening-A review. *J. Hill Agric.*, 9: 7-21.
31. Yeshi, K., D. Crayn, E. Ritmejerytė and P. Wangchuk, 2022. Plant secondary metabolites produced in response to abiotic stresses has potential application in pharmaceutical product development. *Molecules*, Vol. 27. 10.3390/molecules27010313.