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Study of Gibberellic Acid (GA_3) Concentration and Types of Biostimulants Applications on Chili Pepper (*Capsicum frutescens* L.) Production

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Abstract

The study aims to determine the level of atonic concentration and the type of biostimulant that can increase the yield of small chili peppers in the lowlands. The design used was a factorial Randomized Block Design (RBD) consisting of two factors. The first factor is the concentration of atonic (Gibberellic Acid (GA_3)) namely: 0.0 ml/l; 1.5 ml/l, 2 ml/l; and 2.5 ml/l. The second factor is the provision of several types of biostimulants, namely: without biostimulant; Plant Growth Stimulator; EM4; and Superbionic Fertilizer. Data analysis used analysis of variance and if there was significance, further testing was carried out with the Duncan Multiple Range Test. The results showed that the urea fertilizer package with a dose of 200 kg/ha, SP-36 50 kg/ha, and KCl 50 kg/ha gave better seed yields than the control but was not significantly different from higher doses of N, P, K fertilizers.

Keywords: Fertilizer Dosage, Foliar Application, Growth Component, Marginal Soils, Yield Component

1. Introduction

Chili pepper (*Capsicum frutescens L.*) is a vital crop in tropical and subtropical regions, valued for its culinary, medicinal, and economic significance. However, cultivating chili peppers in marginal soils characterized by low organic matter and limited rainfall presents substantial challenges. These abiotic stresses can impede optimal growth and yield, necessitating innovative agricultural practices to enhance productivity under such conditions (Ali et al., 2019; Bhupenchandra et al., 2022). Chili pepper (*Capsicum frutescens* L.) is a vegetable commodity that has received a lot of attention because it has a fairly high economic value. Chili pepper has good business opportunities. The marketing area for chili pepper is quite large because its use is quite extensive. The use of oleoresin - a typical content of chili pepper - which is quite extensive for various food and pharmaceutical industry needs also causes the demand for chili pepper to increase. In addition, the use of chili pepper for typical cooking spices in Bali makes the prospects for this plant in Bali better than other areas (Navia et al., 2020).

The average chili pepper yield in Indonesia has only reached 3-4 tons/ha, and in Bali 1-2 tons/ha (Yohana Feldi Banung, Nyoman Yudiarini & Susanti, 2023). Low chili pepper production is caused by abiotic stresses such as drought and nutrient deficiencies, which hinder growth and nutrient uptake. Additionally, issues with flowering and pollination, influenced by environmental factors, as well as pest and disease attacks, reduce yields. A lack of growth regulators (such as auxin or gibberellin) exacerbates these problems, hindering optimal flowering and fruit development (Ly et al., 2020). This productivity can still be increased with intensification efforts. One of the intensification efforts to achieve increased productivity is to use plant growth regulators. Recently, many synthetic plant growth regulators have been produced which have chemical compositions, properties, mechanisms of action, and physiological effects that are similar to endogenous plant growth regulators, one of which is atonic. The use of growth regulators supplemented with complete macro and micro fertilizers will stimulate growth which will ultimately increase crop yields (Purba et al., 2018).

Atonic is an artificial growth substance containing the active ingredient isomer nitrophenol (sodium ortho-

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nitrophenol 2 g/liter, sodium para-nitrophenol 3 g/liter, sodium 2.4 dinitrophenol 0.5 g/liter, sodium 5 nitroguaiacol 1 g/liter) which functions to stimulate growth, overcome flower loss. Atonic is easily absorbed in plant tissue, accelerates the flow of protoplasm in cells and stimulates rooting so that it can provide strength to all plant cells (Windiyani et al., 2020). Previous studies have shown the effectiveness of Atonic in improving plant growth and yield in various crops. For example, Purba et al. (2021) demonstrated that Atonic significantly enhanced the growth of papaya seeds by stimulating root development and overall growth. Maryam et al., (2023) also found that spraying Atonic on large chili fruits increased yield, particularly in the Padang cultivar. These studies support the positive impact of Atonic on plant growth, but they primarily focus on other crops or specific conditions, such as different chili varieties or soil types. This study differs by focusing on small chili pepper (*Capsicum frutescens* L.) cultivation in marginal soils with low organic matter and limited rainfall, which are common challenges in tropical regions. Unlike previous research, this study investigates the combined effects of Atonic and different biostimulants (EM4, Superbionik, and PGS) on chili production in suboptimal environmental conditions, providing new insights into improving yield and quality in these challenging conditions.

Biostimulants have emerged as a promising solution to mitigate the adverse effects of environmental stresses on plant growth. These substances, which include natural or synthetic compounds, microorganisms, or their combinations, are applied to plants to enhance their growth, development, and stress tolerance. Specifically, biostimulants can improve nutrient uptake, stimulate root development, and enhance resistance to abiotic stresses such as drought and salinity. In particular, the application of biostimulants has been shown to improve plant resilience in marginal soils by enhancing root development, nutrient absorption, and water use efficiency (Nephali et al., 2020; Parmila et al., 2019; Purba et al., 2020).

Atonic, a commonly used biostimulant, contains various natural growth enhancers that have been reported to support plant growth and yield under challenging conditions. While its efficacy has been documented in various crops, limited research exists on its application in chili pepper cultivation, particularly in marginal soils with low organic matter and insufficient rainfall. Understanding the effects of Atonic concentration and the types of biostimulant applications on chili pepper production in these challenging environments is crucial for developing sustainable agricultural practices (Purba et al., 2021). The provision of growth regulators atonic can increase the yield of red chili plants. Spraying atonic 1.5 ml/l and 2.0 ml/l can increase the yield of large chili fruits of the Padang cultivar (Fassya et al., 2020).

EM4 technology is an agricultural cultivation to improve the health and fertility of soil and plants, by using microorganisms that are beneficial for plant growth. EM4 is a mixed culture of beneficial microorganisms originating from Indonesia's nature, beneficial for soil fertility, plant growth and production and environmentally friendly. EM4 contains fermentation and synthetic microorganisms consisting of Lactic Acid bacteria (*Lactobacillus sp*), Photosynthetic Bacteria (*Rhodopseudomonas sp*), *Actinomycetes sp*, *Streptomyces sp* and Yeast and cellulose decomposing fungi, to ferment soil organic matter into compounds that are easily absorbed by plant roots.

Superbionic Fertilizer (Bio Organic), the characteristics of superbionic fertilizer are as follows: 1. Liquid organic fertilizer resulting from fermentation & extraction of various organic compounds and enriched with essential nutrients; 2. Processed with superior technology (biotechnology). Increases fertilization efficiency, stimulates flowering and fruiting; 3. Increases yield and quality (taste, color, shape, health, resistance and uniformity) of food crops, vegetables, fruits, plantations and ornamental plants. Content and composition of Superbionic: C-org (0.5%), C/N-ratio: 0.1, P2O5 (5%), MgO (0.4), N (5%), K2O (8%), CaO (0.5%), S (0.6%). Trace Element: B, Cu, Mn, Fe, Cl, Mo, Zn, Co, other contents: amino acids, growth hormones: cytokinins, gibberellins, and IAA, vitamins, and organic acids: humic and fulvic (Zhang et al., 2021).

Power Growth Stimulator (PGS) is a microbial solution for plant fertilization. PGS is a concept for developing beneficial microorganisms, which are very useful for plants. Green plants are a natural microbial solution that is ready to be used to increase fertility, stress resistance, and productivity. Green plants are developed based on the concept of symbiosis between plants and natural microbes, isolated from the rhizosphere (root) area that is useful for plants (El-Sheshtawy et al., 2015). Previous studies have explored the role of biostimulants in enhancing plant growth and yield under various environmental stresses. For instance, Ranasingha et al. (2024) demonstrated that biostimulants such as EM4 could significantly improve plant resilience to abiotic stresses like drought and salinity, enhancing root development and nutrient uptake. Similarly, Soppelsa et al. (2019) showed that biostimulants like EM4 promoted growth, yield, and fruit quality in strawberries under nutrient-limiting conditions. Moreover, Purba et al. (2020) highlighted the positive effects of biostimulants on shallots in marginal soils, supporting their use to mitigate soil fertility limitations.

Due to the low levels of organic matter in the research area, and the need to use growth stimulants for small chilies on marginal land, research was carried out with the aim of determining the level of atonic concentration and the type of biostimulant that can increase the yield of small chili peppers in the marginal soils. By elucidating the potential benefits of biostimulant applications, this research seeks to provide insights into enhancing chili pepper production under suboptimal conditions, contributing to food security and sustainable agriculture in regions facing similar challenges.

2. Material and Methods

This experiment was conducted in Tembok Village, Tejakula District, Buleleng Regency (-8.170489, 115.448241), from March to September 2024. The altitude is 20 m above sea level. The materials used are small chili seeds *Capsicum frutescens* produced by Riawan Tani Seed, Atonic, EM-4, Superbionik, PGS, Urea fertilizer, SP-36, KCl, PHP mulch, Benlate, Curacron. The tools used are hoes, meters, calipers, electric scales, bamboo stakes, raffia ropes, and others. The method used is an experimental method with a Randomized Block Design consisting of two factors. The first factor is the concentration of atonic, namely: 0.0 ml/l; 1.5 ml/l, 2 ml/l; and 2.5 ml/l. The second factor is the application of several types of biostimulants, namely: without biostimulants; Plant Growth Stimulator; EM4; Superbionic Fertilizer. Each treatment was repeated three times, plot size 4 m x 3 m, distance between plots 50 cm, distance between replications 1 m, planting distance 70 x 60 cm triangle, one bed consists of two rows of plants. Manure 30 tons per hectare, SP-36 400 kg/ha given a week before planting, Urea 500 kg/ha and KCl 400 kg/ha given three times with the same portion, namely one third given at planting time, the second third 40 hst, and the third third 60 hst. Atonic was given at the age of 3 weeks, 6 weeks, and 9 weeks after planting. Superbionic was given 3 times, namely when the plants were 30 hst, 40 hst, and 50 hst. Superbionic was given by spraying it onto the plant canopy with a concentration of 3 cc/l of water. EM-4 was given by spraying the plant canopy with a concentration of 3 cc/liter of water, done 3 times, namely when the plant was 30 hst, 40 hst, and 50 hst. PGS was given by spraying with a dose of 10 cc/liter of water. PGS was given 5 times, namely when the plant was 30 hst, 44 hst, 58 hst, and 72 hst. Pest and disease control used Curacron (2 cc/l) and Benlate (2 g/l), the frequency was adjusted to the level of pest and plant disease attacks.

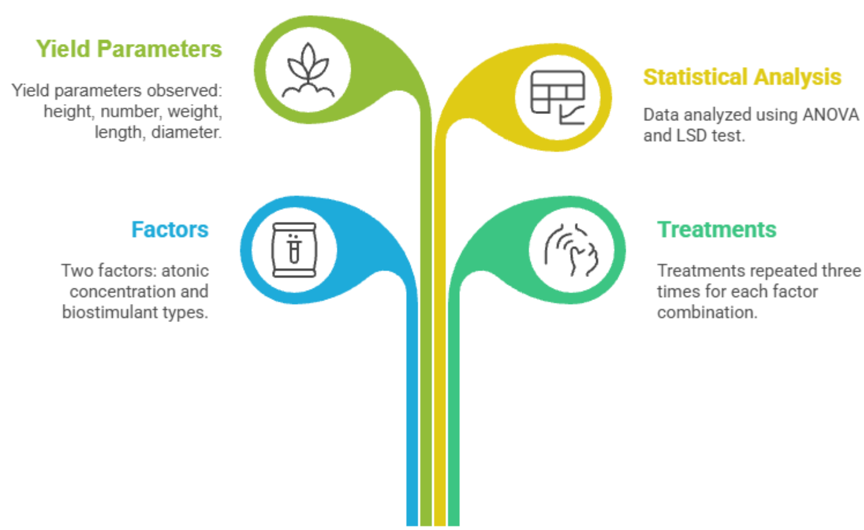

Figure 1. Research Flow Diagram

The observed yield component parameters include:

a. Plant height at the time of the first harvest (cm), measured from the root neck to the highest part of the plant canopy without straightening or pulling the plant canopy.
b. The number of harvested fruits per plant (fruit), the number of fruits observed is the number of fruits harvested. Harvesting is done when the fruit is at least 75% red, the harvest interval is ten days.
c. Harvested fruit weight per plant (g), the observed fruit weight is the weight of the harvested fruit. Harvesting is carried out when the fruit is at least 75% red, the harvest interval is ten days.
d. Average harvested fruit length per fruit (cm), the observed average fruit length is the average fruit length harvested from the first harvest to the last harvest. Fruit length is measured from the base of the fruit to the tip of the fruit. The measurement time and interval are adjusted to the harvest time, namely the interval is ten days.
e. Average harvested fruit diameter per fruit (cm), the observed average harvested fruit diameter is the average

fruit diameter harvested from the first harvest to the last harvest. Fruit diameter is measured using a vernier caliper. Fruit diameter is measured at the largest fruit diameter. The measurement time and interval are adjusted to the harvest time, namely the interval is ten days.

f. Average harvested fruit weight (g), the observed average harvested fruit weight is the average fruit weight harvested from the first harvest to the last harvest. Fruit weight is measured using an electric scale. The measurement time and interval are adjusted to the harvest time, namely the interval is ten days.

The observation data were analyzed using ANOVA, then if a significantly different treatment was shown in the analysis results, the Least Significant Difference (LSD) test at the 5% level was carried out by using SPSS 27.0.1 (Lakitan, 2007).

3. Results and Discussion

Table 1 shows that the combination of atonic concentration and biostimulant treatments significantly affected plant height. The three treatment combinations that produced the highest plant height were A3B1 (127.20 cm), A1B3 (124.200 cm), and A3B2 (124.100 cm), but all three were not significantly different.

The combination of Atonic concentration treatment with biostimulant significantly affected the weight of harvested fruit per plant. The three treatment combinations that produced the highest weight of harvested fruit were A3B3 (1.6067 g), A2B3 and A3B2

Table 1. Effect of atonic, EM-4 biostimulant, Superbionik, and PGS on plant height, weight of harvested fruit per plant, and number of harvested fruit per plant

Treatments	Plant height (cm)	Weight of harvested fruit per plant (g)	Number of fruits harvested per plant (fruit)
A0B0	95.30 ± 3.12 a	0.36 ± 0.01 a	268.11 ± 6.85 a
A0B1	107.00 ± 2.96 bc	0.47 ± 0.01 a	354.82 ± 7.00 ab
A0B2	98.30 ± 1.35 a	0.67 ± 0.03 abc	471.79 ± 9.30 abcde
A0B3	98.80 ± 3.46 ab	0.72 ± 0.01 abcd	485.35 ± 13.07 abcde
A1B0	118.90 ± 1.85 de	0.53 ± 0.01 a	365.42 ± 12.69 abc
A1B1	111.70 ± 2.47 cd	1.02 ± 0.03 cde	587.61 ± 15.78 bcde
A1B2	123.00 ± 2.61 e	0.98 ± 0.03 bcde	655.93 ± 14.48 cde
A1B3	124.20 ± 2.30 e	1.05 ± 0.03 de	702.57 ± 18.07 de
A2B0	122.00 ± 2.20 e	0.66 ± 0.02 abc	475.19 ± 11.99
A2B1	123.70 ± 2.00 e	0.98 ± 0.03 bcde	646.24 ± 14.64 bcde
A2B2	123.67 ± 2.70 e	1.23 ± 0.03 efg	612.79 ± 17.01 bcde
A2B3	122.70 ± 2.53 e	1.55 ± 0.02 gh	1020.78 ± 20.18 fg
A3B0	108.50 ± 2.36 c	0.63 ± 0.02 ab	423.89 ± 13.28 abcd
A3B1	127.20 ± 2.74 e	1.17 ± 0.03 ef	760.58 ± 17.38 ef
A3B2	124.10 ± 2.49 e	1.48 ± 0.02 fgh	1015.45 ± 18.95 fg
A3B3	121.60 ± 2.87 e	1.61 ± 0.03 h	1080.27 ± 19.89 g

Remarks: The same letter behind values of mean of treatment indicates no significant differences among the mean treatment based on The Least Significant Difference (LSD) at 5% probability level and vice versa for different letters. Atonic (A), A0 = 0.0 ml/l; A1 = 1.5 ml/l, A2 = 2 ml/l; and A3 = 2.5 ml/l. Biostimulants (B), B0 = without biostimulant; B1 = Plant Growth Stimulator; B2 = EM4; B3 = Superbionic Fertilizer.

3.1. Plant Height

The treatment with the highest atonic concentration (A3B1) resulted in the tallest plants (127.20 cm), followed by treatments A2B3 (122.70 cm) and A1B3 (124.20 cm). The lowest plant height was observed in treatment A0B0 (95.30 cm), where no biostimulant was applied. This increase in height with higher concentrations of atonic is consistent with findings in other studies, such as those by Patil et al. (2015), who reported that higher doses of atonic significantly promoted plant height in various crops. However, the difference in plant height between the biostimulant treatments (B1, B2, B3) in this study was not as significant, suggesting that the biostimulants may have a lesser effect on plant height compared to atonic concentration.

3.2. Weight of Harvested Fruit per Plant

The weight of harvested fruit showed a similar trend, with treatment A3B3 yielding the heaviest fruit (1.61 g), followed by A3B2 (1.48 g) and A3B1 (1.17 g). The trend of increasing weight with higher atonic concentrations and biostimulant application aligns with studies such as those by Li et al. (2017), which demonstrated that the combination of biostimulants and higher atonic concentrations could significantly enhance fruit yield. In contrast, treatments with lower biostimulant concentrations (B0) had lower fruit weight, indicating that biostimulants could have a notable role in boosting yield.

3.3. Number of Harvested Fruits per Plant

The number of fruits per plant increased significantly with higher atonic concentrations and biostimulants, especially in treatments A3B3 (1080.27 fruits), A3B2 (1015.45 fruits), and A2B3 (1020.78 fruits). These results are consistent with those found by Mansouri et al. (2018), who observed that biostimulants such as EM-4 significantly increased the number of fruits in fruit-bearing plants. It is clear from this study that both atonic concentration and the type of biostimulant play critical roles in increasing the number of fruits harvested per plant. This study shows that increasing the concentration of atonic along with biostimulant application positively influences plant growth parameters, particularly in terms of plant height, fruit weight, and the number of fruits harvested. The use of higher atonic concentrations and biostimulants like Superbionik (A3B3) produced the best outcomes across all parameters, confirming the synergistic effects of atonic and biostimulants on plant development, which is average fruit weight per fruit (1.89 g), average fruit length (4.44 cm), and average fruit diameter (1.19 cm).

Triyanto (2015) found that higher doses of atonic enhanced the growth parameters, particularly plant height and yield. The results in Table 1 align with their conclusions, showing that higher atonic concentrations resulted in taller plants and increased yields. Lamontagne-Drolet (2019) showed that biostimulants like EM-4 positively influenced plant growth, including height and fruit yield. This is consistent with the findings in Table 1, where biostimulants improved the weight and number of harvested fruits. Para\djiković et al. (2019) found that the application of biostimulants significantly increased the number of fruits per plant in fruit-bearing crops. This matches the findings in Table 1, where A3B3 and A2B3 treatments resulted in the highest number of harvested fruits.

Table 2. Effect of administering Atonic, EM-4 biostimulant, Superbionik, and PGS on average fruit weight per fruit, average harvest fruit length, and average number of harvest fruits.

Treatments	Average fruit weight per fruit (g)	Average fruit length (cm)	Average fruit diameter (cm)
A0B0	1.76 ± 0.03 abc	3.83 ± 0.25 a	1.01 ± 0.04 a
A0B1	1.76 ± 0.04 abc	3.86 ± 0.09 ab	1.06 ± 0.02 a
A0B2	1.92 ± 0.01 bcd	3.96 ± 0.17 cd	1.06 ± 0.02 a
A0B3	1.87 ± 0.04 bcd	3.88 ± 0.04 abc	1.06 ± 0.02 a
A1B0	1.76 ± 0.05 abc	3.97 ± 0.04 cde	1.03 ± 0.05 a
A1B1	2.02 ± 0.03 d	3.94 ± 0.09 bcd	1.07 ± 0.04 a
A1B2	2.01 ± 0.04 d	4.09 ± 0.08 g	1.06 ± 0.03 a
A1B3	2.02 ± 0.05 d	4.06 ± 0.09 efg	1.32 ± 0.04 b
A2B0	1.74 ± 0.04 ab	4.01 ± 0.06 defg	1.05 ± 0.04 a
A2B1	1.96 ± 0.04 cd	4.06 ± 0.08 efg	1.08 ± 0.04 a
A2B2	1.85 ± 0.03 bcd	3.98 ± 0.09 def	1.09 ± 0.04 a
A2B3	1.90 ± 0.04 bcd	4.02 ± 0.08 defg	1.09 ± 0.03 a
A3B0	1.65 ± 0.03 a	4.07 ± 0.08 fg	1.06 ± 0.04 a
A3B1	1.88 ± 0.04 bcd	4.09 ± 0.10 g	1.09 ± 0.04 a
A3B2	1.88 ± 0.04 bcd	4.28 ± 0.10 h	1.14 ± 0.04 a
A3B3	1.89 ± 0.03 bcd	4.44 ± 0.11 i	1.19 ± 0.04 ab

Remarks: The same letter behind values of mean of treatment indicates no significant differences among the mean treatment based on The Least Significant Difference (LSD) at 5% probability level and vice versa for different letters. Atonic (A), A0 = 0.0 ml/l; A1 = 1.5 ml/l, A2 = 2 ml/l; and A3 = 2.5 ml/l. Biostimulants (B), B0 = without biostimulant; B1 = Plant Growth Stimulator; B2 = EM4; B3 = Superbionic Fertilizer.

Table 2 presents the effects of atonic, EM-4 biostimulant, Superbionik, and PGS on three fruit characteristics: average fruit weight per fruit, average fruit length, and average fruit diameter. The results are derived from treatments with varying concentrations of atonic and the application of different biostimulants.

3.4. Average Fruit Weight per Fruit

The average fruit weight per fruit ranged from 1.65 g (A3B0) to 2.02 g (A1B1, A1B2, A1B3). The highest weight was observed in the A1 treatments with biostimulants, particularly A1B1, A1B2, and A1B3, which all showed values of 2.02 g. The lowest fruit weight was recorded in the treatment A3B0 (1.65 g). This increase in fruit weight with the application of biostimulants is consistent with findings from previous studies. For example, Soppelsa et al. (2019) reported that biostimulants like EM-4 could significantly enhance fruit weight in fruit-bearing plants, which is reflected in the results here.

Assagaf (2017) research on biostimulants such as EM-4 found that the application of these substances led to significant improvements in fruit weight and size, which is consistent with the results in Table 2, particularly with biostimulants such as EM-4 (A0B2, A1B2, and A2B2).

3.5. Average Fruit Length

The fruit length in the study ranged from 3.83 cm (A0B0) to 4.44 cm (A3B3). The longest fruit length was observed in the A3B3 treatment (4.44 cm), followed closely by A3B2 (4.28 cm). These values are higher than those in the treatments with lower atonic concentrations (e.g., A0B0 with 3.83 cm). Studies such as those by Mansouri et al. (2018) have similarly found that biostimulants contribute to increased fruit size, which aligns with the results in Table 2.

Biostimulants, especially when combined with appropriate fertilizers, enhanced fruit length and diameter. The results in this study mirror their findings, where treatments with biostimulants, particularly A3B3, resulted in the largest fruit lengths and diameters (Mosa et al., 2023).

3.6. Average Fruit Diameter

The fruit diameter ranged from 1.01 cm (A0B0) to 1.32 cm (A1B3). The treatment A1B3 (1.32 cm) produced the largest diameter, followed by A3B3 (1.19 cm). These results suggest that both the higher concentration of atonic and the use of Superbionik (A1B3) contributed to larger fruit diameter. This finding is in line with research by Mosa et al. (2023), who found that biostimulants like Superbionik positively influence the physical characteristics of fruits, including diameter.

Kilic (2024) demonstrated that plant growth stimulators like Superbionik can have a significant impact on fruit diameter. This is supported by the findings in Table 2, where treatments with Superbionik (A1B3, A3B3) resulted in the largest fruit diameters.

4. Conclusion

Based on the results presented in Tables 1 and 2, it can be concluded that the application of atonic with varying concentrations and biostimulants such as EM-4, Plant Growth Stimulator (PGS), and Superbionik significantly influenced plant growth parameters, including plant height, fruit weight per plant, number of harvested fruits, average fruit weight, fruit length, and fruit diameter. Treatments with higher atonic concentrations (2 ml/l and 2.5 ml/l), combined with biostimulants (especially Superbionik), produced the best results in enhancing plant height, yield, and fruit quality, particularly in the A3B3 treatment.

The results of this study suggest that the use of atonic and biostimulants can significantly improve agricultural productivity, particularly in terms of plant growth and fruit quality. This has important implications for increasing crop yields, which can contribute to food security and improve the livelihoods of farmers. The findings also suggest that the application of biostimulants offers a more environmentally friendly alternative to the use of synthetic fertilizers, supporting the adoption of sustainable agricultural practices. Furthermore, this study provides valuable insights into how atonic and biostimulants can be utilized to optimize crop growth, leading to higher quality yields in the agricultural industry.

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