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Growth Responses and Chlorophyll Content of Two Varieties of Tomatoes (*Solanum Lycopersicum* L.) to Natural Plant Growth Regulators

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Abstract. Tomatoes are a popular commodity in Indonesia, with demand increasing every year. The lack of production compared to the demand for tomato commodities requires steps to increase production, one of which is by providing a booster in the form of a natural growth regulator. This study used a Split Plot Design (2x5) with a basic design of Randomized Group Design. The main plot was Tomato Plant Variety, which consisted of two types, namely Fortuna Variety and Servo F1 Variety. The subplots were natural growth regulators consisting of five types: Water, GA_3 100 ppm, Sweet Corn Extract equivalent to 100 ppm GA_3, Shallot Extract equivalent to 100 ppm, and Moringa Leaf Extract equivalent to 100 ppm GA_3. The results showed that the Fortuna tomato variety gave the best results in the parameters of dry weight of biomass per plant and chlorophyll content, while the application of moringa leaf extract gave the best results in the parameter of leaf area.

Keywords: chlorophyll; gibberellin; plant growth regulators; tomato; vegetative

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a horticultural plant widely cultivated and utilized by the community as a cooking ingredient and can be made into various products. Tomato plants are horticultural plants that belong to the Solanaceae family (Dewi & Jumini, 2012). Tomato production in 2023 reached 1,143,790 tons, a decrease of 2.14% from 2022 which reached 1,168,740 tons (Wibowo et al., 2024). Tomato plants have various varieties that are used to support national production, such as Fortuna and Servo F1. FORTUNA tomato plants are semi-determinate tomato plants, while Servo F1 tomatoes are determinate type. Semi-determinate type tomatoes result from crossing indeterminate tomatoes with determinate type tomatoes, and stem growth is not too high (Lumbantobing et al., 2013). Tomato plants can grow well in low to highlands, with a minimum air humidity of 65%, moderate temperatures, and a minimum rainfall of 750 mm per year. Good environmental conditions for tomato plant growth are areas with altitudes between 200-1,500 meters above sea level, with temperatures around 20-27^{o}C, rainfall between 750-1,250 mm.year^{-1}, and air humidity between 65-80% (Sutapa & Kasmawan, 2016).

The growth of tomato plants was stimulated by applying growth regulators. Growth regulators are substances that can affect plant growth and development. The application of growth regulators to plants increases metabolism, growth, and production in plants (Irfan, 2013). Growth regulators consist of two types, namely natural and artificial growth regulators which have advantages and disadvantages of each. Agrogibb 40 SL was one type of artificial plant growth regulator (PGR) containing GA_3, which played a role in increasing vegetative growth by stimulating cell division and elongation and stimulating the formation and development of flowers. Agrogibb 40 SL contains active ingredients that can increase vegetative growth and generative development of flowers. One of the main components of Agrogibb 40 SL is a synthetic hormone that contains active ingredients in the form of GA3 or gibberellin acid as much as 40%. Application of GA_3 at certain concentrations had been proven to increase plant growth. Application of GA_3 with a concentration of 100 ppm on plants increased growth and yield as shown in the increase in fruit weight (Permatasari et al., 2016).

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Natural ingredients such as shallots, sweet corn, and moringa leaves were used as the main ingredients for making natural plant growth regulators (PGR). Sweet corn extract was used as a source of natural PGR because it contained hormones that could increase the growth of tomato plants. Sweet corn plant extract contains cytokinin and gibberellin hormones, so it could be used as a source of natural PGR (Rinaldi et al., 2019). Sweet corn extract also contains cytokinin hormones in the form of zeatin and gibberellin which can spur shoot growth. Sweet corn extract contains gibberellin 41.23 ppm shoot growth. Sweet corn extract contains gibberellin 41.23 ppm, auxin 1.67 ppm, and cytokinin in the form of zeatin 3.94 ppm (Khairuna, 2017). Shallot extract could have been used as a natural PGR because it contained auxins, cytokinins, and gibberellins. Shallot extract contained auxin, zeatin, kinetin, thiamin, rhizocalin, gibberellin, and riboflavin which could have helped plant growth (Dule & Murdaningsih, 2017). The composition of ZPT in shallots is auxin in the form of IAA, gibberellin, and cytokinin in the form of zeatin and kinetin. Identification of 100 grams of fresh shallots shows the content of growth hormones in the form of auxin IAA at 156.1 ppm, cytokinin in the form of zeatin at 122.34 ppm, and gibberellin at 230.67 ppm (Kurniati et al., 2019). Giving shallot extract increased vegetative growth, especially root length, and giving a combination of sweet corn extract and shallot extract gave the best results on the number of tomato fruits (Rinaldi et al., 2019). Moringa leaves were one of the materials that could have been used as natural PGR. Moringa leaves contained various kinds of hormones that stimulated the growth of tomato plants. The content of cytokinins in the form of zeatin, kinetin, and gibberellin in moringa leaves increased plant growth so they could have been used as a source of natural PGR (Warohma et al., 2018). Moringa leaf extract has a fairly high cytokinin content compared to auxin and gibberellin. Fresh moringa leaves as much as 100 grams contain 2.491 mg of cytokinin, 0.62 mg of auxin in the form of IAA, and 6.09 mg of gibberellin (Latif & Mohamed, 2016). Based on the previous report, several plant-based extracts, such as shallot, sweet corn, and moringa leaves extract had potential substances that may influenced plant growth. The application of such natural PGRs may be a promising environmentally friendly technique that can replace artificial growth regulators to improve the quality of plant growth such as increasing plant height through cell elongation, as well as other supporting qualities such as chlorophyll levels in tomato plants related to the photosynthesis process.

METHODS

Place and date

The research was conducted from November 2022 - March 2023 at Coblong Vegetable Field, Pakopen Village, Bandungan District, Semarang Regency, Central Java. Parameter analysis and observations were conducted at the Laboratory of Plant Ecology and Production, Department of Agriculture, Faculty of Animal Science and Agriculture, Diponegoro University.

Research Preparation

The preparation of planting materials included planting media preparation, tillage, and weed removal. Thirty beds were made, each with a size of 1.5 x 1 m, a height of about 20 - 40 cm, a planting distance for each plant of 50 cm, and a distance of 30 cm between beds. The finished beds were covered with plastic mulch. The process of making natural growth regulators included creating natural growth regulators from sweet corn, shallot, and moringa leaves. The preparation of natural PGR with a concentration of 100% was carried out by mashing the main ingredients, namely sweet corn (2425 grams), shallot (433.5 grams), and moringa leaves (1642 grams). The extract was then obtained by filtering, and the growth regulator solution was mixed with 1 liter of water. The amount

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of ingredients used to make natural PGR has been adjusted based on the sources (Khairuna, 2017; Kurniati et al., 2019; Latif & Mohamed, 2016). The control treatment consisted of a negative control, which was water, and a positive control, which was GA_3 at 100 ppm. This was achieved by mixing Agrogibb 40 SL at 0.25 ml into 1 liter of water.

Seed Sowing

The seed sowing stage included the process of sowing seeds in seedling plastic until they reached the age of 14 HST and were then transferred to the field for the maintenance stage. Seedling plastic was filled with planting media in the form of soil, and each plastic was filled with one seed. Sixty seeds of Servo and Fortuna tomato seeds each were sown, then sprayed with water once a day until germination. Seedlings were transplanted to the field at the age of 14 weeks after planting. More than the specified number of seeds were sown for replanting purposes.

Application of Treatment

The treatment of natural PGR was done by spraying water and each growth regulator with a volume of about 50 ml for each plant and applied once every three weeks, namely 21 weeks after planting, 42 weeks after planting, 63 weeks after planting, and 84 weeks after planting.

Plant Maintenance

Fertilization was given with the recommended dose of fertilization using a single fertilizer, including Urea at 125 $kg.ha^{-1}$, ZA at 300 $kg.ha^{-1}$, TSP at 250 $kg.ha^{-1}$, and KCl at 200 $kg.ha^{-1}$. The application of Urea, ZA, and KCl fertilizers was done before transplanting, and supplementary fertilization was carried out after 4 weeks of planting with a dose of 5 grams per plant, 12 grams per plant, and 8 grams per plant, respectively. TSP fertilizer was applied after transplanting at 10 grams per plant. Urea and KCl fertilization could be continued at 7 and 10 weeks after planting with a dose of 5 grams per plant and 8 grams per plant, respectively. Weeding was done once a week manually by pulling weeds, and pest and disease control were carried out if necessary. Control was done by planting tomatoes with plastic mulch, and manually removing pests, and the last control that could be done was by spraying Metarhizium with the recommended dose. Harvesting was done at the age of the plant between 65-90 weeks after planting. The first harvesting of tomato plants was done when the fruit had ripened to approximately 30%. Subsequent harvests were carried out every 2 - 3 days after the first harvest, allowing for 10 - 15 picking times in one season.

Parameter Observation and Data Analysis

Observations were made on the parameters of plant growth and chlorophyll content. The variables observed were plant height, number of compound leaves per plant, wet weight of plant biomass, dry weight of plant biomass, leaf area, chlorophyll content, and carotenoid content. The data obtained were processed according to the analysis of variance or ANOVA followed by the Duncan Multiple Range Test (DMRT) at a 5% level.

RESULTS AND DISCUSSION

Based on the results of the analysis of variance (ANOVA), varieties, growth regulators, and their interaction did not significantly affect the parameters of plant height and number of compound leaves. The detail can be seen in Figure 1.

Figure 1 showed that the height of tomato plants of Fortuna variety at 4 weeks after planting ranged from 44.83 - 52.83 cm with an average of 51.1 cm. The height of tomato plants of Servo variety at 4 weeks after planting ranged from 46.83 - 50.33 cm with an average of 47.83 cm. The number of compound leaves of the Fortuna variety at 4 weeks after planting ranged from 12 - 15.33 strands with an average of 14.13 strands. The number of compound leaves of the Servo variety at 4 weeks of planting ranged from 14.67 to 17.33 strands with an average of 16 strands.

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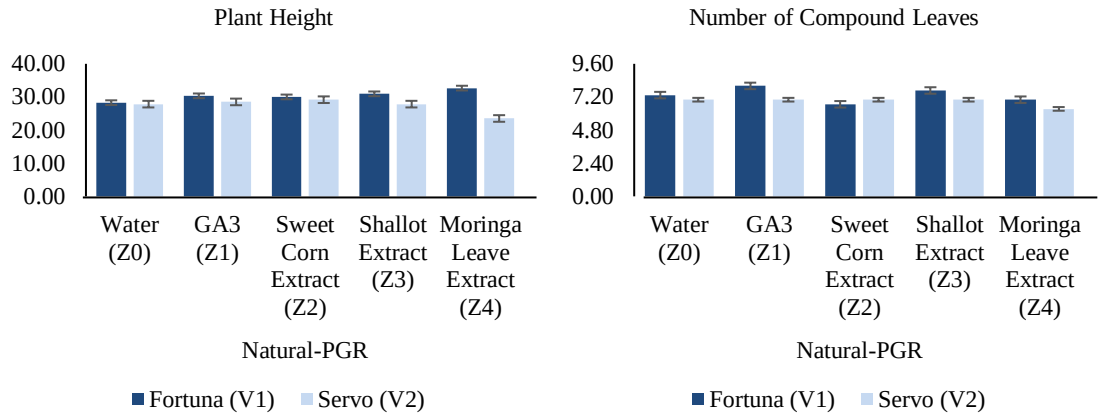

Figure 1. Vegetative growth response of tomato as affected by variety and natural-PGR.

Differences in Fortuna and Servo varieties did not affect the height of the tomato and the number of compound leaves at 4 weeks after planting (Figure 1). This was because both varieties had relatively similar plant height results during the vegetative phase. After all, determinate tomatoes stopped growing when they entered the generative phase. Gatahi (2020) stated that tomatoes with determinate growth types could grow to a maximum height of 120 cm and will stop growing when entering the generative phase. Tomato plants are divided into several types of growth, with Fortuna tomatoes included in the semi-determinate type, while Servo tomatoes are included in the determinate type. Tujuba & Negash (2020) stated that tomato plants are divided into three types of growth such as determinate, semi-determinate, and indeterminate. The table shows almost the same results because the data was taken in the first 4 weeks of growth; the difference in growth is not too significant because indeterminate tomatoes will begin to grow steadily after the flowering period, which is 5 weeks after planting.

The application of GA_3 and natural PGR did not have a significant effect on the height of tomato plants (Figure 1). This is due to the relationship between gibberellin performance and plant conditions. Maxiselly et al. (2021) stated that the effect of GA_3 on stem elongation depends on plant conditions, if endogenous gibberellins are low, then GA_3 will have a significant effect. The application of natural growth regulators and GA_3 did not affect the number of compound leaves of tomato plants because the application of growth regulators had been done once before the generative phase, causing less optimal leaf growth. Muhyidin et al. (2018) stated that the application of hormones at the end of the vegetative period and the beginning of the generative period inhibited the absorption of hormones, so they tended not to affect vegetative growth. Application of gibberellin hormone in certain concentrations can help increase the number of leaves on solanum family plants such as tomatoes and eggplants. Based on the research of Triani et al. (2020), gibberellin with a concentration of 200 ppm can increase the number of leaves on eggplant plants compared to the control treatment without gibberellin. GA_3 plays a role in various important processes such as seed germination, root and shoot elongation, flowering process, and fertilization. Chen et al. (2020) stated that gibberellins could improve the performance of various important processes in plants such as seed germination, stem and hypocotyl elongation, flower formation and development, and fruit formation and maturation.

Based on the results of the analysis of variance (ANOVA), it was shown that varieties had no effect on the wet weight of plant biomass, but they did affect the dry weight of plant biomass. Additionally, growth regulators and the interaction of the

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two did not significantly affect the parameters of the wet weight of plant biomass and dry weight of plant biomass. The detail can be seen in Table 1.

Table 1. Tomato plant biomass as affected by variety and natural-PGR.

Variety	Natural-PGR					Mean
	Water (Z_0)	GA_3 (Z_1)	Sweet Corn Extract (Z_2)	Shallot Extract (Z_3)	Moringa Leaves Extract (Z_4)	
	Wet weight of plant biomass					
	----------gr----------					
Fortuna (V_1)	316,20	393,87	273,07	342,20	225,03	310,07
Servo (V_2)	137,37	222,87	196,03	114,80	191,20	172,45
Mean	226,78	308,37	234,55	228,50	208,12	241,26
Variety	Natural-PGR					Mean
	Water (Z_0)	GA_3 (Z_1)	Sweet Corn Extract (Z_2)	Shallot Extract (Z_3)	Moringa Leaves Extract (Z_4)	
	Dry weight of plant biomass					
	----------gr----------					
Fortuna (V_1)	45,90	60,63	39,99	57,69	44,69	49,78[a]
Servo (V_2)	18,71	30,21	36,02	27,20	26,34	27,69[b]
Mean	32,31	45,42	38,01	42,45	35,51	38,74

Note: Mean values followed by the same letter in a column and row are not significantly different according to Duncan's multiple range test ($P < 0.05$).

The results in Table 1 demonstrated that the wet weight of biomass of tomato plants of Fortuna variety ranged from 225.03 - 393.87 gr with an average of 310.07 gr. The wet weight of tomato biomass of Servo variety ranged from 114.8 - 222.87 gr with an average of 172.45 gr. Duncan's Multiple Range Test based on Table 1 indicated that varieties significantly affected the dry weight of plant biomass. The Fortuna variety displayed a significantly higher dry weight of plant biomass, which was 49.78 gr, compared to the Servo variety, which was 27.69 gr.

The difference between Fortuna and Servo varieties did not significantly affect the wet weight of tomato plant biomass (Table 1) because it was related to the growth of tomato plants in the vegetative phase. Both varieties showed relatively the same growth in the vegetative phase, resulting in similar wet-weight results. Suptijah et al. (2010) stated that the wet weight of plants is derived from the storage of CO_2 assimilation results during the vegetative growth phase. Variety differences had a real influence on the dry weight parameters of plant biomass. The Fortuna variety produced a higher dry weight of plant biomass than the Servo variety. This was due to genetic differences in Fortuna varieties that allowed them to grow until the end of the planting period and produce more biomass. (Naibaho et al., 2019) stated that the Fortuna tomato variety yielded the best results in crown and root dry weight and was considered one of the varieties capable of producing high biomass.

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The application of natural PGR and GA_3 did not have a significant effect on the wet weight of plant biomass (Table 1) because endogenous gibberellin levels in plants are sufficient to produce plant biomass. (Handoko et al., 2022) stated that the content of gibberellin in plants played a role in cell division and elongation, which, along with the cell size, influenced the wet weight of the plant. The application of natural-PGR and GA_3 did not have a significant effect on the dry weight of plant biomass. This was because the gibberellin levels in the plant were sufficient to facilitate important processes for plants, such as enlarging cell size, which contributed to the increase in the dry weight of plant biomass. This was supported by Febrianto & Budi Sutoto (2019) stated that GA_3 could increase the size of plant cells, resulting in additional weight of the plant. The hormone gibberellin, which is produced internally by the plant, is able to increase the size of the plant by lengthening the stem and roots, so if the size of the plant is enlarged, the wet and dry weight of the plant also increases. Based on Yusidah & Nurirhani (2022), gibberellin and auxin are hormones that play a role in the extension and increase in stem and root size.

Based on the results of the analysis of variance (ANOVA), it was shown that growth regulators had a significant effect on leaf area parameters, while varieties and their interactions had no significant effect on leaf area parameters. The detail can be seen in Table 2.

Table 2. Tomato leaf area as affected by variety and natural-PGR.

Variety	Natural-PGR					Mean
	Water (Z_0)	GA_3 (Z_1)	Sweet Corn Extract (Z_2)	Shallot Extract (Z_3)	Moringa Leaves Extract (Z_4)	
	----------cm^2----------					
Fortuna (V_1)	2212,70	2493,00	2333,03	2580,53	2652,53	2454,36
Servo (V_2)	2022,83	2045,57	2198,13	2717,17	2685,27	2333,79
Mean	2117,77^c	2269,28^b	2265,58^b	2648,85^{ab}	2668,9^a	2394,08

Note: Mean values followed by the same letter in a column and row are not significantly different according to Duncan's multiple range test ($P < 0.05$).

The results of Duncan's Multiple Range Test based on Table 2 indicated that natural-PGR significantly affected the leaf area of tomato plants. The treatment of moringa leaf extract resulted in a significantly higher leaf area than the water treatment but was not significantly different from the shallot extract treatment. Moringa leaf extract showed a leaf area of 2648.85 cm^2, while water treatment showed a leaf area of 2117.77 cm^2.

The differences between Fortuna and Servo varieties did not have a significant effect on the leaf area of tomato plants (Table 2). Fortuna tomato plants, which continued to experience vegetative growth until the end of the planting period, produced more leaves with smaller leaf sizes compared to Servo tomato plants. Consequently, the leaf area of both varieties tended to be similar. Tomato plants with a larger number of leaves tend to have smaller leaf sizes because the photosynthesis results are distributed among many leaves.

The application of natural PGR had a significant effect on leaf area (Table 2). Moringa leaf extract yielded higher leaf area results than other treatments. This was attributed to gibberellin in moringa leaf extract, which could increase pigment and the photosynthesis rate in leaves, subsequently enhancing leaf area. Yuniati et al. (2022) stated that a high content of pigments in the leaves would increase the rate of photosynthesis, leading to an increase in leaf area.

Based on the results of the analysis of variance (ANOVA), it was shown that varieties had a significant effect on

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chlorophyll content but had no effect on carotenoid content, as well as growth regulators, and the interaction of the two did not significantly affect the parameters of chlorophyll and carotenoid content. The detail can be seen in Table 3.

Table 3. Tomato plant chlorophyll content as affected by variety and natural-PGR.

Variety	Natural-PGR					Mean
	Water (Z_0)	GA_3 (Z_1)	Sweet Corn Extract (Z_2)	Shallot Extract (Z_3)	Moringa Leaves Extract (Z_4)	
	Chlorophyll content					
	----------mg.L^{-1}----------					
Fortuna (V_1)	20,82	15,63	15,30	19,78	19,53	18,21[a]
Servo (V_2)	15,12	15,75	18,25	16,88	18,77	16,96[b]
Mean	17,97	15,69	16,78	18,33	19,15	17,58
Variety	Natural-PGR					Mean
	Water (Z_0)	GA_3 (Z_1)	Sweet Corn Extract (Z_2)	Shallot Extract (Z_3)	Moringa Leaves Extract (Z_4)	
	Carotenoid content					
	----------mg.L^{-1}----------					
Fortuna (V_1)	572,81	599,83	619,24	561,99	540,90	578,96
Servo (V_2)	477,58	510,96	606,54	482,49	542,53	524,02
Mean	525,19	555,40	612,89	522,24	541,71	551,49

Note: Mean values followed by the same letter in a column and row are not significantly different according to Duncan's multiple range test ($P < 0.05$).

The results of Duncan's Multiple Range Test based on Table 3 indicated that the variety had a significant effect on chlorophyll levels. The Fortuna variety displayed significantly higher chlorophyll levels of 18.21 mg.L^{-1} than the Servo variety which amounted 16.96 mg.L^{-1}. The carotenoid content of tomato plants of the Fortuna variety ranged from 540.9 - 619.24 mg.L^{-1} with an average of 578.96 mg.L^{-1}. Carotenoid content of tomato plants of the Servo variety ranged from 477.58 - 606.54 mg.L^{-1} with an average of 578.96 mg.L^{-1}.

Fortuna varieties displayed higher chlorophyll levels than Servo varieties (Table 3). This was likely related to the shape of the tomato leaves of Fortuna varieties which tended to be longer, potentially having a larger leaf area with high chlorophyll content. This was following Afiatan et al., (2022) which stated that high chlorophyll levels are related to leaf area, where the larger leaf area increased chlorophyll levels in the leaves. Differences in Fortuna and Servo varieties did not have a significant effect on carotenoid levels (Table 3). This occurred because the formation and composition of carotenoids were influenced by genetic factors, and plants of the same species tended to have similar carotenoid compositions. This was in line with Liu et al., (2015) which stated that the composition of carotenoids is largely determined by genetic factors in plants.

The application of natural PGR and GA_3 did not have a significant effect on chlorophyll content (Table 3) because the gibberellin content in the plant was sufficient to support important processes, such as increasing plant leaf area which resulted in high chlorophyll content. This was supported by Santo-Pereira et al., (2017) who stated that gibberellin accelerated plant development,

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increased leaf area, and raised chlorophyll and carotenoid levels. The application of natural PGR and GA_3 did not have a significant effect on carotenoid levels (Table 3). The external application of gibberellin was not effectively absorbed by plants because the endogenous gibberellin content influenced plant growth and biomass, leading to a decrease in carotenoid levels and performance. This was explained by Kössler et al. (2021) who stated that the reduction in plant biomass is due to a decrease in photosynthetic performance due to the low amount of carotenoids.

CONCLUSION

Based on the research conducted, it can be concluded that the Fortuna tomato variety gave the best results in the parameters of dry weight of biomass per plant and chlorophyll content, while the application of moringa leaf extract gave the best results in the parameter of leaf area. The application of natural PGR and GA_3 had a positive effect on a small number of parameters observed. This was probably because the concentration of natural PGR given had not been able to provide a real influence on most parameters. It is necessary to test the content of natural PGR to find out how many concentrations were expected to have a positive effect on plants.

REFERENCES

Afiatan, A. S., Sumarantini, C. M., & Badrudin, U. (2022). The capillary system irrigation applications using wick and variety media methods at the tomato plant (Solanum lycopersicum). *BIOFARM: A Scientific Journal of Agriculture*, *18*(2). https://jurnal.unikal.ac.id/index.php/biofarm/article/view/2471

Chen, R., Fan, Y., Yan, H., Zhou, H., Zhou, Z., Weng, M., Huang, X., Lakshmanan, P., Li, Y., Qiu, L., & Wu, J. (2020). Enhanced activity of genes associated with photosynthesis, phytohormone metabolism and cell wall synthesis is involved in gibberellin-mediated sugarcane internode growth. *Frontiers in Genetics*, *11*. https://doi.org/10.3389/fgene.2020.570094

Dewi, P., & Jumini. (2012). Growth and yield of two tomato varieties in response to various fertilizers. *J. Floratek*, *7*, 76–84. https://jurnal.usk.ac.id/floratek/article/view/521

Dule, B. R., & Murdaningsih. (2017). The use of natural auxin as a growth regulator (PGR) on the growth of water guava (Syzygium samarangense) seedling cuttings. *AGRICA*, *10*(2). https://doi.org/10.37478/Agr.V10i2.197

Febrianto, M., & Budi Sutoto, S. (2019). The effect of giving gibberellin on the growth and yield of cherry tomatoes (Lycopersicon esculentum Var. Cerasiforme) in various of planting media with substrate hydroponic systems. *AGRIVET*, *25*, 25–37. http://eprints.upnyk.ac.id/id/eprint/17988

Gatahi, D. M. (2020). Challenges and opportunities in tomato production chain and sustainable standards. In *International Journal of Horticultural Science and Technology* (Vol. 7, Issue 3, pp. 235–262). University of Tehran, College of Aburaihan. https://doi.org/10.22059/ijhst.2020.300818.361

Handoko, A., Lusmaniar, & Oksilia. (2022). The effect of bio-fertilizer concentration and the use of two tomato varieties on tomato plants production (Lycopersicum esculentum Mill). *Agronitas Journal of Agricultural Sciences*, *4*(2). https://ejournal.unitaspalembang.com/index.php/ags/article/view/153

Irfan, M. (2013). Response of shallot (Allium ascalonicum L.) to growth regulators and nutrients. *Journal of Agrotechnology*, *3*(2), 35–40. https://doi.org/10.24014/ja.v3i2.86

Khairuna. (2017). *Improvement of micro tuber production of Solanum tuberosum*

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i1.1745

L. granola variety with young corn extract enhancer. [Dissertation, North Sumatra Islamic State University]. http://repository.uinsu.ac.id/5621/1/00000878.pdf

Kössler, S., Armarego-Marriott, T., Tarkowská, D., Turečková, V., Agrawal, S., Mi, J., De Souza, L. P., Schöttler, M. A., Schadach, A., Fröhlich, A., Bock, R., Al-Babili, S., Ruf, S., Sampathkumar, A., & Moreno, J. C. (2021). Lycopene β-cyclase expression influences plant physiology, development, and metabolism in tobacco plants. *Journal of Experimental Botany*, *72*(7), 2544–2569. https://doi.org/10.1093/jxb/erab029

Kurniati, F., Hartini, E., & Solehudin, A. (2019). Effect of type of natural substances plant growth regulator on nutmeg (Myristica fragrans) seedlings. *Agrotechnology Research Journal*, *3*(1), 1–7. https://doi.org/10.20961/agrotechresj.v3i1.25792

Latif, H. H., & Mohamed, H. I. (2016). Exogenous applications of moringa leaf extract effect on retrotransposon, ultrastructural and biochemical contents of common bean plants under environmental stresses. *South African Journal of Botany*, *106*, 221–231. https://doi.org/10.1016/j.sajb.2016.07.010

Liu, L., Shao, Z., Zhang, M., & Wang, Q. (2015). Regulation of carotenoid metabolism in tomato. *Molecular Plant*, *8*(1), 28–39. https://doi.org/10.1016/j.molp.2014.11.006

Lumbantobing, E., Kardhinata, H., & Rosmayati. (2013). Growth and production responses of several black soybean varieties (Glycine max L.) based on seed sizes. *Journal of Agroecotechnology*, *1*(3). https://doi.org/10.32734/jaet.v1i3.2639

Maxiselly, Y., Anjasari, I. R. D., Sutari, W., Ariyanti, M., Soleh, M. A., Sari, R. A., & Chiarawipa, R. (2021). Stimulation effect of synthetic plant growth regulator (GA3 and BAP) on young cinchona plant (Cinchona ledgeriana) grown in lowland. *IOP Conference Series: Earth and Environmental Science*, *743*(1). https://doi.org/10.1088/1755-1315/743/1/012016

Muhyidin, H., Islami, T., & Maghfoer, M. D. (2018). Effect of concentration and timing of gibberellin application on growth and yield of tomato plants (Lycopersicon esculentum Mill.). *Journal of Plant Production*, *6*(6), 1147–1154. http://protan.studentjournal.ub.ac.id/index.php/protan/article/view/759

Naibaho, D., Hanafiah, D. S., & Tampubolon, K. (2019). Stress susceptibility index and heritability of tomato varieties to aluminum treatment with nutrient culture media. *International Journal of Scientific and Technology Research*, *8*(09). https://www.ijstr.org/final-print/sep2019/Stress-Susceptibility-Index-And-Heritability-Of-Tomato-Varieties-To-Aluminum-treatment-With-Nutrient-Culture-Media.pdf

Permatasari, D. A., Sri Rahayu, Y., & Ratnasari, E. (2016). Effect of Gibberellin hormones on the formation of parthenocarpy fruit of tomato varieties tombatu F1. *LenteraBio: Biology Scientific Periodical*, *5*(1). http://ejournal.unesa.ac.id/index.php/lenterabio

Rinaldi, A., Ambar, A. A., Nurilmi, Harsani, & Rahim, I. (2019). Growth and production of tomatoes treated with natural growth hormones of corn extract and shallot extract. *Proceedings of the National Seminar on Multidisciplinary Synergy of Science and Technology*, *2*, 26–27. https://jurnal.yapri.ac.id/index.php/semnassmipt/article/view/112

Santo-Pereira, A. E., Silva, P. M., Oliveira, J. L., Oliveira, H. C., & Fraceto, L. F.

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i1.1745

(2017). Chitosan nanoparticles as carrier systems for the plant growth hormone gibberellic acid. *Colloids and Surfaces B: Biointerfaces*, *150*, 141–152. https://doi.org/10.1016/j.colsurfb.2016.11.027

Suptijah, P., Jacob, A. M., & Mursid, S. (2010). The role of chitosan in tomato growth enhancement (Lycopersicum esculentum) during vegetative phase. *AKUATIK: Journal of Aquatic Resources*, *4*(1). https://mail.journal.ubb.ac.id/akuatik/article/view/411

Sutapa, G. N., & Kasmawan, I. G. A. (2016). Mutation induction effects of 60 Co gamma radiation on physiological growth of tomato (Lycopersicon esculentum L.) plants. *Journal Of Radiation Safety And Environment*, *1*(2). www.batan/ptkmr/jrkl

Triani, N., Permatasari, V. P., & Guniarti, G. (2020). Effect of concentration and frequency of gibberellin (GA3) on growth and yield of eggplant plants (Solanum melongena L. cv. antaboga-1). *Agro Bali: Agricultural Journal*, *3*(2), 144–155. https://doi.org/10.37637/ab.v3i2.575

Tujuba, M., & Negash, G. A. (2020). Evaluation of released tomato (Lycopersicon esculentum Mill.) varieties for fruit yield and quality parameters in Western Ethiopia. *Agricultural and Biological Sciences Journal*, *6*(2), 100–113. http://www.aiscience.org/journal/absjhttp://creativecommons.org/licenses/by/4.0/

Warohma, M., Karyanto, A., & Rugayah. (2018). Effect of two types of natural growth regulators on the growth of mangosteen seedlings (Garcinia mangostana L.). *Journal of Tropical Agroetech*, *6*(1), 15–20. https://doi.org/10.23960/jat.v6i1.2527

Wibowo, A. S., Irjayanti, A. D., Khairunnisa, D. A., Stiyaningsih, H., Putri, I. M., Areka, S. K., & Nurfalah, Z. (2024). *Horticulture Statistics 2023* (Vol. 5). Central Bureau of Statistics.

Yuniati, N., Kusumiyati, K., Mubarok, S., & Nurhadi, B. (2022). The role of moringa leaf extract as a plant biostimulant in improving the quality of agricultural products. *Plants*, *11*(17). https://doi.org/10.3390/plants11172186

Yusidah, I., & Nurirhani, P. (2022). Response of red spinach plants resistance by inducer spent mushroom substrate of straw to P. xylostella attack. *Agro Bali : Agricultural Journal*, *5*(3), 616–624. https://doi.org/10.37637/ab.v5i3.1029