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# Improvement Of Siam Banjar Orange Seedling Performance Through Strangulation And Application Of Plant Growth Regulators

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***Abstract:***
***Background****: Siam Banjar orange cultivated in South Kalimantan holds significant potential to become a key fruit commodity in Indonesia. To enhance its productivity, various methods, including seedling growth manipulation through strangulation and the use of Plant Growth Regulators (PGRs) during the vegetative phase, can be employed. Strangulation aims to improve plant performance, thereby increasing productivity, while the use of PGRs aims to regulate growth and improve fruit quality during the generative phase.*
***Materials and Methods****: This research utilized a Randomized Complete Block Design (RCBD) with two tested factors. The first factor involved double strangulation (s), with four treatment levels: $s_0$ (control), $s_1$ (5-5 cm height of double strangulation), $s_2$ (5-10 cm height of double strangulation), and $s_3$ (5-15 cm height of double strangulation). The second tested factor was the application of PGRs (z), with three treatment levels: $z_0$ (control), $z_1$ (75 ppm BAP), and $z_2$ (150 ppm BAP). Each treatment was replicated four times, totaling 48 experimental units, with each experimental unit consisting of two orange seedlings.*
***Results****: The research results showed that the effect of giving cow manure significantly differed on all growth parameters and eggplant yields.*
***Conclusion:*** *The increase in doses of cow manure and NPK fertilizer showed a positive linear relationship, where the relative growth rate, plant growth rate, net assimilation rate, fruit diameter, fruit length, fruit quantity, fruit weight per plant, and fruit weight per eggplant plant also increased.*
***Keywords:*** *Banjar orange, vegetative growth, plant growth regulators (PGRs), strangulation and fruit quality.*

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## I. Introduction

The horticulture sector, encompassing fruit crops, vegetables, and ornamental plants, plays a crucial role in meeting a country's agricultural needs. In Indonesia, oranges have become one of the popular agricultural products after bananas and mangoes (Wulandari, 2014). Siam oranges (*Citrus suhuensis*) have experienced rapid growth in the last decade in Indonesia, particularly in the South Kalimantan province. Siam oranges are suitable for tidal swamp land and are known by various names such as Pontianak oranges, Mamuju, Batu, Madang oranges, and Mahang oranges, with local variations including Siam Banjar oranges in South Kalimantan (Noor, 2012). The primary production center for Siam Banjar oranges is located in the Banjar Regency, South Kalimantan, especially in the Astambul District, which produced 11,290 tons in 2021 (BPS, 2022).

The physical appearance of plants, or plant performance, serves as an indicator of plant performance that influences its growth and development. Plant performance modifications, such as stem pruning, thinning, and branch bending, have been undertaken to enhance the architecture of citrus plants (Rai, 2018).

Siam Banjar oranges often face issues of irregular branch growth, few branches, and a tendency to grow straight upward. Therefore, actions such as strangulation treatment in the vegetative phase are needed to manipulate seedling growth, shaping stronger and more open primary and secondary branches. Strangulation treatment can restrict the translocation of carbohydrates from leaves to roots and vice versa, stimulating carbohydrate accumulation in the canopy, promoting new shoot growth, fruit formation, and fruit development (Susanto *et al*., 2002).

The use of Plant Growth Regulators (PGRs), such as BAP and KNO3, can also influence plant growth, flowering, fruit formation, and fruit quality. Aliyah's research (2016) indicates that the combination of strangulation and the use of growth regulators in Pamelo orange seedlings improves branch length, branch number, leaf area, and the C/N ratio.

Currently, strangulation treatment and the use of PGRs in citrus plants during the vegetative phase are not widely practiced. Strangulation and the application of growth regulators can lead to better formation of

vegetative shoots, facilitating the establishment of seedling architecture during the vegetative phase. Establishing plant canopy structure early on can enhance plant productivity as it enters the production phase.

## II. Material and Methods

This research constitutes a field study on strangulation and PGRs to improve the performance of Siam Banjar oranges.

**Study Design:** The research employed a Randomized Complete Block Design (RCBD) with two factors. The first factor was double strangulation (s) with four levels: $s_0$ (control without strangulation), $s_1$ (double strangulation with a distance of 5 cm between wires and a height of 5 cm from the grafting point), $s_2$ (double strangulation with a distance of 5 cm between wires and a height of 10 cm from the grafting point), and $s_3$ (double strangulation with a distance of 5 cm between wires and a height of 15 cm from the grafting point). The second factor was Plant Growth Regulators (PGRs) (z) with three levels: $z_0$ (control without PGR), $z_1$ (Application of BAP type Plant Growth Regulator at 75 ppm), and $z_2$ (Application of BAP type Plant Growth Regulator at 150 ppm). There were a total of 12 combinations of treatments, with each treatment replicated four times as groups, resulting in a total of 48 experimental units. Each experimental unit consisted of two orange seedlings.

**Study Location:** The study was conducted at the greenhouse of the Plant Protection and Horticulture Agency (BPTPH) of South Kalimantan Province, and the Laboratory of the Faculty of Mathematics and Natural Sciences, Lambung Mangkurat University, Indonesia.

**Study Duration:** The research was conducted for 6 months from September 2022 to March 2023.

**Procedure methodology**

Observation components include vegetative and physiological growth components of the plants. Observations were conducted at 1 week after treatment (WAT), 4 WAT, and 8 WAT. After 2 months, strangulation treatment and the application of Plant Growth Regulators (PGR) were performed on Siam Banjar citrus seedlings. Strangulation was released, and observations continued for 10 weeks, 14 weeks, and 22 weeks. The growth observation components consist of plant height, number of shoots, number of branches, stem diameter, stem rigidity, leaf area, number of leaves, canopy width, carbohydrate content, nitrogen, and leaf chlorophyll.

**Statistical analysis**

The data analysis was conducted using the F Test (ANOVA) at a significance level of $\alpha = 0.05$. If the analysis of variance for the tested treatments showed a significant effect, the Duncan Multiple Range Test (DMRT) was further conducted at the significance level of $\alpha = 0.05$, and the BNT test was performed to examine mean differences for individual factors. If the data did not follow a normal distribution, the Kruskal-Wallis test was employed to assess median differences between groups.

## III. Result and Discussion

**Plant height, leaf carbohydrate content, leaf nitrogen content, and leaf chlorophyll content**

The interaction between strangulation treatment and the application of PGRs on Siam Banjar orange seedlings showed a significant effect on plant height, leaf carbohydrate content, leaf nitrogen content, and leaf chlorophyll content, as indicated in Table 1. The plant height of Siam Banjar orange seedlings was significantly influenced by the interaction between strangulation treatment and PGR application. The highest plant height for Siam Banjar orange seedlings was observed in the double strangulation with a distance of 5 cm between wires and a height of 15 cm from the grafting point, without PGR ($s_3z_0$) treatment with an average of 8.15 cm, but it did not significantly differ from the double strangulation with a distance of 5 cm between wires and a height of 10 cm from the grafting point, with BAP-type PGR at 75 ppm ($s_2z_1$) treatment with an average of 7.40 cm, as well as the double strangulation with a distance of 5 cm between wires and a height of 15 cm from the grafting point, with BAP-type PGR at 75 ppm ($s_3z_1$) and double strangulation with a distance of 5 cm between wires and a height of 10 cm from the grafting point, without PGR ($s_2z_0$) treatments with averages of 7.25 cm. However, this treatment significantly differed from the others. Strangulation stimulates ethylene hormone production and reduces competitive shoot growth, while the absence of BAP reduces shoot competition, enhances plant physiological activity, thus resulting in optimal plant height increase.

**Table 1. The effect of interaction between strangulation treatment and PGR application on plant height (cm), leaf carbohydrate content (%), leaf nitrogen content (%), and leaf chlorophyll content (%) of Siam Banjar orange seedlings at 22 WAT.**

| Treatment | Plant Height (cm) | Leaf Carbohydrate Content (%) | Leaf Nitrogen Content (%) | Leaf Chlorophyll Content (%) |
|---|---|---|---|---|
| $s_0z_0$ | 6.45[b] | 1.13[e] | 1.11[d] | 2.51[cde] |
| $s_0z_1$ | 6.74[b] | 1.46[de] | 1.20[cd] | 2.50[cde] |
| $s_0z_2$ | 6.69[b] | 2.22[c] | 1.26[cd] | 2.50[cde] |
| $s_1z_0$ | 6.92[b] | 2.75[ab] | 1.29[cd] | 2.68[bc] |
| $s_1z_1$ | 7.12a[b] | 1.46[de] | 1.25[cd] | 2.74[b] |
| $s_1z_2$ | 6.85[b] | 2.56[bc] | 1.69[a] | 2.93[a] |
| $s_2z_0$ | 7.25[ab] | 1.35[de] | 1.26[cd] | 2.42[de] |
| $s_2z_1$ | 7.40[ab] | 1.61[d] | 1.28[cd] | 2.34[e] |
| $s_2z_2$ | 7.19[ab] | 2.38[bc] | 1.43[bc] | 2.74[b] |
| $s_3z_0$ | 8.15[a] | 2.99[a] | 1.25[cd] | 2.35[de] |
| $s_3z_1$ | 7.25[ab] | 1.29[de] | 1.52[ab] | 2.49[de] |
| $s_3z_2$ | 6.99[b] | 2.41[bc] | 1.71[a] | 2.53[cd] |

Note: Numbers followed by the same letter in the same column, indicate no significant difference based on the DMRT test at a 5% significance level.

The analysis of leaf carbohydrate content revealed a significant synergistic effect of the interaction between strangulation and BAP application. The highest leaf carbohydrate content was found in the double strangulation with a distance of 5 cm between wires and a height of 15 cm from the grafting point, without PGR ($s_3z_0$) treatment with an average of 2.99%, not significantly different from the double strangulation with a distance of 5 cm between wires and a height of 5 cm from the grafting point, without PGR ($s_1z_0$) treatment but significantly different from the other treatments. This indicates that the interaction between strangulation and the absence of BAP stimulates carbohydrate production as an adaptive response to nutrient restriction. The synergy between the two factors assists the plant in increasing its capacity to produce carbohydrates through photosynthesis.

The leaf nitrogen content of Siam Banjar orange seedlings was also influenced by the interaction between strangulation and BAP application. The highest leaf nitrogen content was observed in the double strangulation with a distance of 5 cm between wires and a height of 10 cm from the grafting point, with BAP-type PGR at 150 ppm ($s_3z_2$) treatment with an average of 1.71%, not significantly different from the double strangulation with a distance of 5 cm between wires and a height of 5 cm from the grafting point, with BAP-type PGR at 150 ppm ($s_1z_2$) and double strangulation with a distance of 5 cm between wires and a height of 15 cm from the grafting point, with BAP-type PGR at 75 ppm ($s_3z_1$) treatments, but significantly different from the other treatments. This suggests a synergistic effect between these two factors. Strangulation stimulates carbohydrate production, while BAP stimulates protein and amino acid synthesis, resulting in an increase in nitrogen content in the leaves.

Leaf chlorophyll content showed a significant response to the interaction between strangulation and PGR application. The highest leaf chlorophyll content was found in the double strangulation with a distance of 5 cm between wires and a height of 5 cm from the grafting point, with BAP-type PGR at 150 ppm ($s_1z_2$) treatment with an average of 2.93%, significantly different from the other treatments. The synergy between strangulation and BAP enhances photosynthesis, respiration, and transpiration activities, leading to an increase in chlorophyll content in the leaves of Siam Banjar orange seedlings.

The complexity of the interaction between strangulation and BAP application in modulating growth and metabolite content in Siam Banjar orange seedlings is evident. Their positive interaction significantly influences plant physiological activities, especially in carbohydrate, nitrogen, and chlorophyll production, ultimately contributing to plant growth and performance.

**Number of shoots, canopy width, and number of leaves**

The influence of single factors, strangulation, and the application of BAP PGR on Siam Banjar orange seedlings showed a significant effect on shoot growth, canopy width, and the number of leaves, as indicated in Table 2. The number of shoots in strangulation treatment on Siam Banjar orange seedlings showed that the double strangulation with a distance of 5 cm between wires and a height of 15 cm from the grafting point ($s_3$) treatment had the highest number of shoots with an average of 10.62 shoots; this treatment did not significantly differ from the other treatments but significantly differed from the S0 treatment. Meanwhile, the single PGR treatment in the

Application of BAP type PGR at 150 ppm ($z_2$) treatment had the highest number of shoots with an average of 10.71 shoots; this treatment did not significantly differ from the other treatments but significantly differed from the control ($z_0$) treatment.

Strangulation treatment stimulates shoot formation by restricting nutrient flow, influencing shoot growth and development. The application of BAP PGR stimulates shoot growth through enzyme activation and metabolic processes. The increase in the number of shoots in Siam Banjar orange seedlings, resulting from strangulation and PGR application, not only affects shoot growth itself but also has an impact on nitrogen, chlorophyll, and carbohydrate content in the plant.

**Table 2. The effect of single factors of strangulation treatment and pgr application on the number of shoots, canopy width (cm), and number of leaves of Siam Banjar orange seedlings at 22 WAT.**

| Treatment | Observation Variable | | |
|---|---|---|---|
| | Number of Shoots | Canopy Width (cm) | Number of Leaves |
| | Strangulation | | |
| $s_0$ | $8.75^{b}$ | $2.25^{ab}$ | $53.87^{c}$ |
| $s_1$ | $9.70^{ab}$ | $2.24^{ab}$ | $54.66^{bc}$ |
| $s_2$ | $10.33^{a}$ | $1.81^{b}$ | $57.20^{ab}$ |
| $s_3$ | $10.62^{a}$ | $2.63^{a}$ | $57.79^{a}$ |
| | Plant Growth Regulators (PGRs) | | |
| $z_0$ | $9.19^{b}$ | $1.75^{b}$ | $53.12^{c}$ |
| $z_1$ | $9.65^{ab}$ | $2.14^{ab}$ | $55.81^{b}$ |
| $z_2$ | $10.71^{a}$ | $2.43^{a}$ | $58.71^{a}$ |

Note: Numbers followed by the same letter in the same column indicate no significant difference based on the BNT test at a 5% significance level.

The analysis of canopy width growth showed that the single strangulation factor in the double strangulation with a distance of 5 cm between wires and a height of 15 cm from the grafting point ($s_3$) treatment had the widest canopy with an average of 2.63 cm. This treatment did not significantly differ from the other treatments but significantly differed from the double strangulation with a distance of 5 cm between wires and a height of 10 cm from the grafting point ($s_2$) treatment. Meanwhile, in the BAP PGR treatment in the Application of BAP type PGR at 150 ppm ($z_2$) treatment, the widest canopy width was observed with an average of 2.43 cm. This treatment did not significantly differ from the other treatments but significantly differed from the control ($z_0$) treatment.

The strangulation factor stimulates canopy growth by promoting branch formation and inhibiting nutrient flow, resulting in wider canopy growth. The application of BAP PGR stimulates canopy growth through meristem activation and cell division, thus providing a stimulus for canopy growth, creating a broader canopy.

Furthermore, regarding the growth of the number of leaves, the analysis results showed that the single strangulation treatment in the double strangulation with a distance of 5 cm between wires and a height of 15 cm from the grafting point ($s_3$) treatment had the highest number of leaves with an average of 57.79 leaves. This treatment did not significantly differ from the other treatments but significantly differed from the control ($s_0$) and Double strangulation with a distance of 5 cm between wires and a height of 5 cm from the grafting point ($s_1$) treatments. Meanwhile, in the BAP PGR treatment in the Application of BAP type PGR at 150 ppm ($z_2$) treatment, the highest number of leaves was observed with an average of 58.71 leaves. This treatment did not significantly differ from the other treatments but significantly differed from the control ($z_0$) treatment.

Strangulation affects nutrient and water flow at the bottom of Siam Banjar orange seedlings, ultimately influencing leaf growth. The increase in the number of leaves is the plant's response to compensate for nutrient and energy flow restrictions resulting from strangulation. The application of BAP PGR stimulates leaf growth, creating plants with a higher leaf count. The application of BAP PGR at the right dosage stimulates new leaf growth in Siam Banjar orange seedlings. BAP PGR stimulates new leaf growth and shoot proliferation, contributing to an increase in the number of leaves.

The increase in the number of shoots, canopy width, and the number of leaves in Siam Banjar orange seedlings, resulting from strangulation and PGR application, not only affects the growth of these characteristics but also impacts the nitrogen, chlorophyll, and carbohydrate content in the plant. A higher number of shoots enhances photosynthesis capacity and nutrient resources in the plant, resulting in healthier and more productive plants.

The single influence of strangulation and BAP PGR application on Siam Banjar orange seedlings contributes positively to shoot growth, canopy width, and the number of leaves. Strangulation enhances shoot

growth by restricting nutrient flow, while BAP PGR application stimulates meristem activity and cell division, creating plants with a wider canopy and a higher number of leaves.

**Stem strength**

The observations conducted over 22 WAT on the stem strength of Siam Banjar orange seedlings are presented in Figure 1.

**Figure 1. The effect of strangulation treatment with PGR application on the stem strength of 22 WAT Siam Banjar orange seedlings.**

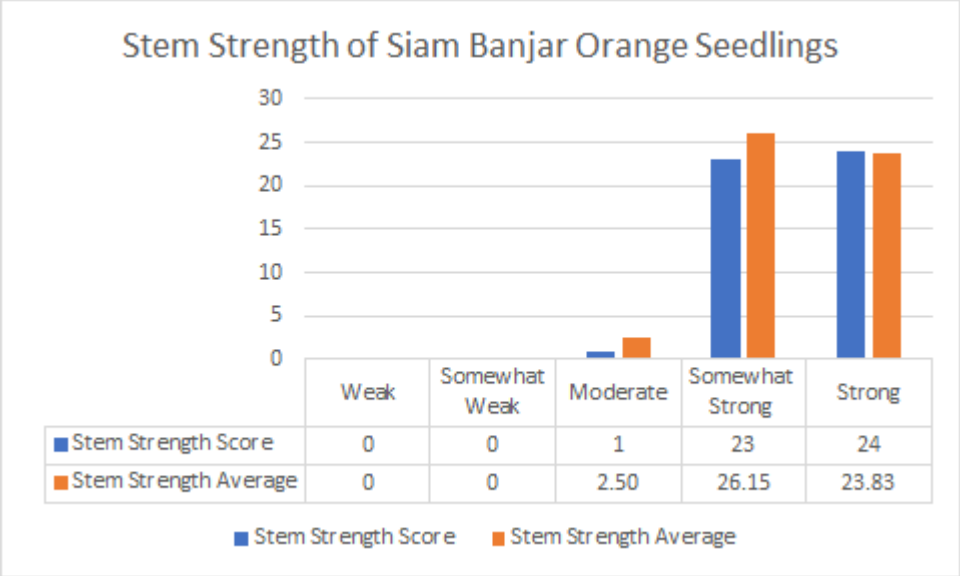


Figure 1 illustrates the results of the Kruskal-Wallis analysis with stem strength categories: weak (1), somewhat weak (2), moderate (3), somewhat strong (4), and strong (5). The average results depicted in Figure 1 suggest that the observation of stem strength in Siam Banjar orange seedlings can be categorized as somewhat strong. This categorization is based on the highest average ranking being in the somewhat strong category (26.15), followed by strong (23.83), and moderate (2.50).

**Number of branches, upper stem diameter, and leaf area**

The analysis results indicate that there is no significant effect on the number of branches, upper stem diameter, and leaf area of Siam Banjar orange seedlings at 22 WAT due to the interaction or single factors of strangulation treatment and PGR application.

**Table 3. Average number of branches, upper stem diameter (cm), and leaf area ($cm^2$) of 22 WAT Siam Banjar orange seedlings in strangulation treatment with PGR application.**

| Treatment | Observation Variable | | |
|---|---|---|---|
| | Number of Branches (Fruits) | Upper Stem Diameter (cm) | Leaf Area ($cm^2$) |
| $S_0Z_0$ | 7.13 | 1.98 | 2.96 |
| $S_0Z_1$ | 6.75 | 2.13 | 3.35 |
| $S_0Z_2$ | 6.88 | 2.64 | 3.29 |
| $S_1Z_0$ | 6.38 | 2.14 | 3.04 |
| $S_1Z_1$ | 7.5 | 2.3 | 3.19 |
| $S_1Z_2$ | 7.38 | 2.29 | 3.31 |
| $S_2Z_0$ | 6.25 | 1.83 | 3.29 |
| $S_2Z_1$ | 7.13 | 1.63 | 3.34 |
| $S_2Z_2$ | 7.5 | 1.98 | 3.05 |
| $S_3Z_0$ | 5.38 | 2.58 | 3.23 |
| $S_3Z_1$ | 6.5 | 2.5 | 3.34 |
| $S_3Z_2$ | 9.5 | 2.83 | 3.29 |

Despite the potential of strangulation treatment by tying the plant stem and PGR application to influence plant growth, within the specified time frame, both treatments did not show a significant impact on the observed

parameters. The average growth results indicate that the number of branches ranges from 5.38 to 9.50, upper stem diameter ranges from 1.63 cm to 2.83 cm, and leaf area ranges from 2.96 $cm^2$ to 3.35 $cm^2$.

## IV. Conclusion

The present study reveals a significant interaction effect between the application of strangulation and PGR on Siam Banjar orange seedlings, that is plant height, leaf carbohydrate content, nitrogen content, and chlorophyll content. Moreover, each individual treatment of strangulation and PGR application independently affects the number of shoots, canopy width, and the number of leaves in Siam Banjar orange seedlings. Notably, the double strangulation treatment, with a distance between wires of 5 cm and a height of wire 15 cm from the bud eye combine without PGR application, proves effective in enhancing plant height and leaf carbohydrate content. Additionally, the combination between double strangulation with a distance between wires of 5 cm and a height of wire 15 cm from the bud eye and PGR application (BAP 75 ppm), resulting in increased plant height and leaf nitrogen content. These findings contribute to valuable insights in optimizing the growth and physiological characteristics of Siam Banjar orange seedlings for enhanced its productivity.

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