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Growth performance of seaweed (*Kappapicus alvarezii*) in tissue culture with immersion of NPK and TSP fertilizer

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ABSTRACT

The seaweed *Kappaphycus alvarezii* is an economically important commodity to be developed in Indonesia. In order to facilitate its development, the use of tissue culture-derived seedlings is necessary. This study aims to evaluate the growth performance of tissue culture-derived *K. alvarezii* through the immersion of NPK and TSP fertilizers. The research was conducted from March to May 15, 2020, in the waters of Sumberkencono village, Wongsorejo sub-district, Banyuwangi regency, East Java. The seaweed seedlings were obtained from the Brackishwater Aquaculture Center in Situbondo. The fertilizer treatments applied were Treatment A (NPK 2 g L^{-1}), Treatment B (NPK 1 g L^{-1} + TSP 1 g L^{-1}), Treatment C (TSP 1 g L^{-1}), and Treatment D (Control) immersed for 15 minutes. The data were processed and analyzed using IBM SPSS version 22 with One-Way ANOVA and Duncan's post hoc test. The NPK fertilizer used in the treatments had a composition of 15% Nitrogen (N), 15% Phosphate (P_2O_5), and 15% Potassium (K) at a dose of 2 g L^{-1} The TSP fertilizer had a composition of 18% Phosphate (P_2O_5) at a dose of 2 g L^{-1} L^{-1}. Additionally, a combination of NPK 1 g $L^{-1}$and TSP 1 g L^{-1} was immersed for 15 minutes, and a control group without immersion was included. The results showed that the seaweed growth with the immersion of NPK+TSP fertilizer achieved better growth performance (Absolute weight 57.48 grams, SGR 7.21 %, Thallus length 8.5 cm, diameter 6.52 mm).

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1. Introduction

Seaweed (*Kappaphycus alvarezii*) has the potential to be a promising aquaculture commodity with a wide market share, both in the local and international markets (Anggadiredja et al., 2011). However, the production conditions of seaweed in Indonesia are still suboptimal (KKP, 2015). The dry seaweed productivity in Indonesia only reaches 1.14 tons/km, a significantly lower figure compared to other countries such as the Solomon Islands, which reach 4.55 tons/km, and Tanzania, India, and the Philippines, which reach 1.61 tons/km. One of the factors suspected to contribute to the low seaweed productivity in Indonesia is its slow growth rate. Therefore, one of the efforts that can be undertaken to increase seaweed production is through the use of fertilization.

Fertilization is a common method used in agriculture to provide the necessary nutrients to plants (Sutejo, 2002). Although marine environments are considered nutrient-rich, fertilization for plants living in water bodies is still rarely practiced. However, to significantly enhance seaweed production, it is not sufficient to rely solely on the nutrients available in the natural environment. Therefore, the application of fertilizer to seaweed (*K. alvarezii*) is crucial in order to fulfill the adequate and balanced nutritional requirements, ultimately achieving optimal production results.

Fertilization in seaweed can help improve plant growth and production. Fertilizers contain various essential nutrients such as nitrogen, phosphorus, and potassium that can influence plant growth (Hartati et al., 2018). In this study, the addition of NPK (Nitrogen, Phosphorus, Potassium) and TSP (Triple Super Phosphate) fertilizers was performed in the tissue culture of seaweed (*K. alvarezii*) to accelerate its growth. It is expected that with the addition of these fertilizers, seaweed growth can be significantly enhanced, thereby increasing productivity and achieving optimal results.

Tissue culture has become an important method in the development of seaweed (*K. alvarezii*) in recent years. Tissue culture allows efficient vegetative propagation of plants and can consistently produce high-quality seedlings (Plachno et al., 2016). In the context of this research, tissue culture is used to accelerate seaweed growth and enhance productivity through the addition of NPK and TSP fertilizers. With advancements in tissue culture and ongoing research, it is anticipated that seaweed production (*K. alvarezii*) can continue to be significantly improved (Phang et al., 2015). The utilization of better tissue culture technologies and a deeper understanding of growth factors will help optimize seaweed growth, increase productivity, and make a greater contribution to the aquaculture industry.

2. Material and methods

The research was conducted from March to May 2020, at Desa Sumberkencono, Kec. Wongsorejo, Kab. Banyuwangi, and Balai Perikanan Budidaya Air Payau Situbondo, East Java.

This study utilized a completely randomized design (CRD) experiment. This design is the simplest experimental design for field experiments, with randomization done using colored strings as differentiators between treatments. The colors used for each treatment were as follows: NPK (Blue), NPK+TSP (Green), TSP (Orange), Control (Red). The observed data included absolute growth, specific growth rate, and water quality suitability. The study was replicated 9 times. The treatments included in the research activities were as follows:

Treatment A: Soaking with NPK fertilizer at 2 g/l (Fendi et al., 2019)

Treatment B: Soaking with NPK fertilizer at 1 g/l + TSP at 1 g/l

Treatment C: Soaking with TSP fertilizer at 2 g/l (Abida & Firman, 2010)

Treatment D: Without soaking (Control)

The appropriate dosage of fertilizer for each treatment was dissolved in a plastic bucket containing 10 L of seawater. The prepared seaweed seedlings were placed and soaked in the fertilizer solution for 15 minutes. The soaking duration was based on previous studies (Aliyas et al., 2019). The study utilized 36 seaweed samples. The research design is presented in Fig. 1.

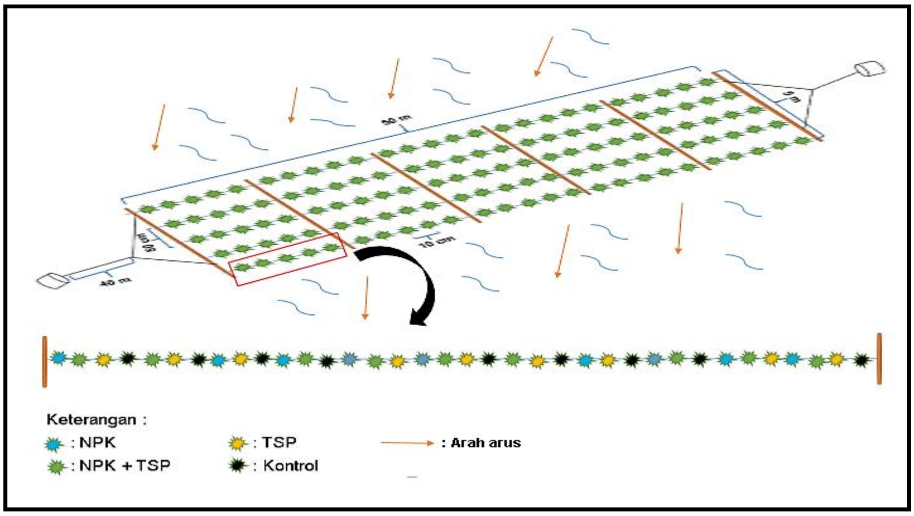

Fig. 1. Seaweed planting layout

2.1 Procedure

Longline Cultivation Vessel Preparation

The steps involved in preparing the longline cultivation vessel are as follows: Arrange the main line to form a square shape, attaching main floats at each corner and adding auxiliary floats in the middle to maintain the construction's size. The spreader lines are tied to the main line at intervals of 100-200 cm. A point line is attached to each spreader line with a distance of 20 cm between points. The constructed framework is floated on the water surface and anchored in place using anchor weights, with the anchor rope length being three times the water depth at each corner and the auxiliary floats.

Seaweed Seedling Preparation

The steps involved in preparing the seaweed seedlings are as follows: The tissue-cultured seaweed seedlings are obtained from the Tissue Culture Unit of BPBAP Situbondo and undergo a minimum outdoor adaptation period of 30 days. Select seedlings based on the following criteria: abundant branches, absence of spots, absence of epiphytic organisms, and disease-free. Weigh the seedlings according to the treatment plan. Transport the seedlings in styrofoam containers suitable for seaweed. Upon arrival at the site, gently disperse the seedlings into the cultivation vessel to prevent breakage.

Seaweed Seedling Soaking

The steps involved in seaweed seedling soaking are as follows: Fill a container with seawater and add the respective treatment fertilizer. Place the seedlings in a container filled with water and fertilizers, allowing them to soak for 15 minutes.

Seaweed Seedling Tying

The steps involved in tying the seaweed seedlings are as follows: Attach the seedlings to the point lines at intervals of 25-30 cm, with each point weighing 20-50 g (Fadilah, 2015). Use ribbon knots for securing the seedlings, keeping them slightly loose. The tying process is performed on land, ensuring that the seedlings remain moist or wet.

Seaweed Maintenance

The steps involved in seaweed maintenance are as follows: Inspect the seaweed daily to remove debris. Check the condition of the seaweed cultivation vessel for looseness or damaged nets. Monitor and address any broken or diseased seaweed. Maintain cleanliness of the seaweed by removing any adhering foreign objects such as mud and dirt. Take measures to address any attacks by sea urchins by removing and disposing of them appropriately.

Water Quality

The steps involved in monitoring water quality are as follows: Regular water quality checks are conducted twice a day, in the morning (08:00) and afternoon (12:00), with the following parameters observed: temperature, turbidity, salinity, pH, and water current velocity. The measurement methods for water quality are as follows:

a. Temperature is measured using an alcohol thermometer.

b. Turbidity is measured using a secchi disk. Salinity is measured using a refractometer.

c. Water current velocity is measured using a current drougue. pH is measured using a Schott instrument.

d. Nitrate and phosphate levels are measured using an HACH Colorimeter DR/850.

Growth Monitoring

Sampling is conducted every 7 days by collecting 10% of the total seaweed population. The sampling procedure involves weighing the seaweed thallus, counting the thalli, and measuring thallus diameter using calipers. The measurement results are recorded using a suitable measurement form for each parameter.

2.2 Data Analysis

Absolute Weight

To calculate absolute growth, the following formula can be used (Effendie, 2000 in Pratama et al., 2017):

$$G = Wt - Wo$$

where G = Absolute growth (g), Wo = Initial weight of the seedlings (g), Wt = Weight of the seedlings on day t (g)

Daily Growth Rate

The specific growth rate (SGR) or daily growth rate can be calculated using the formula proposed by Fogg (1975) in Fikri et al. (2015):

$$SGR = \frac{\ln Wt - \ln Wo}{t} \times 100\%$$

where SGR = Specific growth rate (%), Wo = Initial weight of the seedlings (g), Wt = Weight of the seedlings on day t (g), t = Duration of the cultivation period (days).

The data were analyzed using IBM SPSS Statistics version 22 software with the One-Way ANOVA analysis method, followed by Duncan's test to determine significant differences in the weight of the seaweed K. alvarezii cultured through tissue culture. Additionally, water quality data were analyzed using descriptive analysis, comparing them with the SNI 7672:2011 standard or existing literature on seaweed aquaculture water quality.

3. Results and Discussion

3.1. Absolute Weight of Seaweed

Based on the research results, it was found that treatment (A), which involved soaking with NPK, resulted in an absolute weight ranging from 26.22 to 47.89 grams. Treatment (B), which involved soaking with NPK + TSP, yielded an absolute weight ranging from 32.44 to 71.44 grams. Treatment (C), which involved soaking with TSP, resulted in an absolute weight ranging from 22.67 to 43 grams, while the Control group had an absolute weight ranging from 17.78 to 28.33 grams. The highest tendency of absolute weight growth was observed in the NPK+TSP treatment, followed by the NPK treatment, then the TSP treatment, with the Control group exhibiting the lowest weight. The absolute weight of seaweed at each sampling point can be seen in Fig. 2.

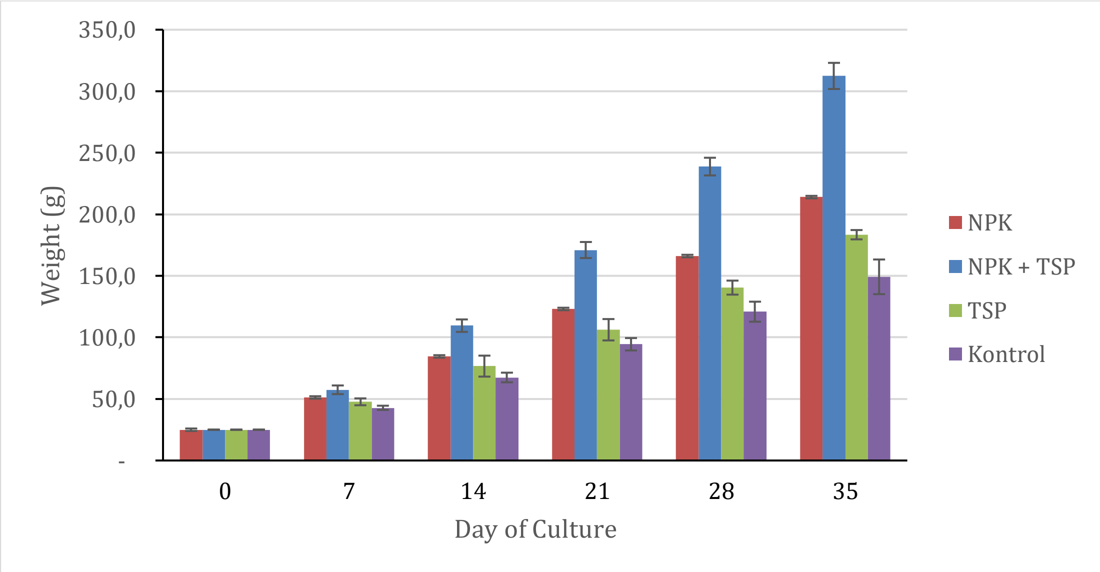

Fig. 2. Final weight of *K. Alvarezii*

From Figure 2, it can be observed that the absolute weight of seaweed increased relative to each sampling point in all treatments. This is consistent with the findings of Amiluddin (2017), who stated that, in general, the wet weight of seaweed increases over time, notably from the second week until harvest, under normal conditions. The differences in absolute weight growth among the seaweed treatments are attributed to the availability of nutrient elements required for seaweed growth. In the Control group (Treatment D), the absolute weight of seaweed was relatively lower, which is likely due to the nutrient elements being solely derived from the environment. In contrast, in Treatments A (NPK), B (NPK+TSP), and C (TSP), the nutrient elements necessary for growth were obtained not only from the environment but also from the fertilizer treatments. This is supported by the findings of Umasugi & Abdussabar (2019), who suggested that when plants are supplied with fertilizer, the required nutrient elements for seaweed are optimally available, leading to increased cell growth and, consequently, an increase in seaweed weight. The percentage increase in absolute weight of seaweed with the TSP treatment (43.00 grams) was 51.78% higher than that of the Control group (28.33 grams), 69.04% higher than the NPK treatment (47.89 grams), and the highest weight gain was observed in the NPK + TSP treatment (73.67 grams) with a 160% increase compared to the Control group.

An analysis of variance (ANOVA) was performed on the absolute weight data to assess the significance of the seaweed soaking treatments using NPK fertilizer, the combination of NPK and TSP fertilizers, TSP fertilizer alone, and no fertilizer soaking. The results indicated that each treatment significantly influenced the absolute weight of the seaweed ($p < 0.05$). Duncan's multiple range test was then conducted, revealing that the NPK+TSP treatment (Treatment B) exhibited the best daily weight growth, which significantly differed ($p < 0.05$) from Treatments A (NPK), C (TSP), and D (no fertilizer). The lowest average weight growth was observed in Treatment D (no fertilizer). The results of the ANOVA can be seen in Appendix 2.

Furthermore, Duncan's multiple range test was performed to determine the smallest significant difference in the absolute weight of seaweed among the treatments. The test revealed significant differences in absolute weight between each treatment and the Control group. The highest absolute weight was achieved in the NPK+TSP treatment (57.48 g), followed by the NPK treatment (37.80 g), the TSP treatment (31.69 g), and the Control group (24.844 g).

Fertilizers contain essential nutrients that are vital for plant growth, including seaweed. Seaweed absorbs nutrients through diffusion across its entire thallus or stem surface. These nutrients are utilized by seaweed as raw materials for the process of photosynthesis, which is then used to form its body tissues, leading to growth. Therefore, seaweed greatly relies on nutrients for its growth. Additionally, seaweed requires various nutrient compositions for growth, such as macronutrients like N & P (Harrison & Hurd, 2001).

It is believed that seaweed successfully absorbs nutrients present in fertilizer solutions during the soaking process. This is evidenced by the difference in seaweed growth between treatments with fertilizer soaking and those without. Seaweed subjected to the soaking treatment has an optimal supply of nutrients required for its growth, as it receives additional nutrients from the fertilizer in addition to those obtained from the environment. The fertility of seaweed is also influenced by the content of nitrate, phosphate (Majid, 2018), and potassium (Harrison & Hurd, 2001). Nitrogen (N) plays a role in stimulating growth, as a deficiency in nitrogen can inhibit growth by slowing down the process of photosynthesis. Phosphate (P) is an essential factor in photosynthesis, and its deficiency can result in stunted growth, fewer shoots, and slower growth (Kushartono et al., 2009). Furthermore, phosphate can enhance plant activity in metabolic processes (Majid, 2018). Potassium (K) is used by plant cells during the assimilation of energy produced by photosynthesis (Kushartono et al., 2012; Setiaji et al., 2012). In the case of Treatment D without fertilizer soaking, the nutrients obtained solely come from elements dissolved in the water, making seaweed growth entirely dependent on the fertility of the water.

The difference in absolute weight of seaweed in each soaking treatment is likely due to variations in nutrient uptake by seaweed during the soaking process. The highest absolute weight is obtained when seaweed is soaked in a combination of NPK+TSP fertilizer, as seaweed absorbs a complete and balanced nutrient composition, including N, P, and K, for its growth, compared to treatments where only NPK or TSP fertilizer is used for soaking.

3.2. Specific growth rate

Specific growth rate (SGR) of seaweed was measured for each treatment during the observation period. The range of SGR obtained in Treatment (A), which involved soaking with NPK fertilizer, ranged from 3.62% to 10.25%. Treatment (B), which involved soaking with a combination of NPK+TSP fertilizer, resulted in SGR values ranging from 3.71% to 11.88%. Treatment (C), involving soaking with TSP fertilizer, yielded SGR values of 3.82% to 9.22% per day, while the control group, without any treatment, showed SGR values of 3.54% to 9.76%. The highest SGR tendency was observed in the NPK+TSP treatment, followed by the NPK treatment, then the TSP treatment, and the lowest was the control group. The specific growth rates observed can be seen in Fig. 3.

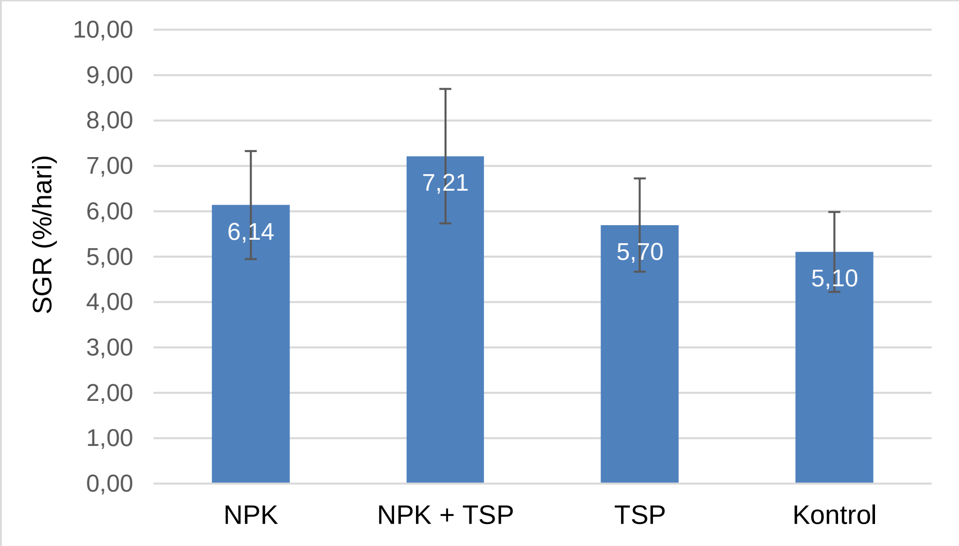

Fig. 3. Spesific growth rate of *K. alvarezii*

The observed differences in specific growth rate among the treatments are likely due to the soaking treatments, where the seaweed absorbed and utilized the provided fertilizer to develop new tissues. However, the seaweed without any treatment exhibited relatively low SGR due to the absence of fertilizer soaking, leading to the lack of additional nutrient absorption and relying solely on the nutrients present in the surrounding water.

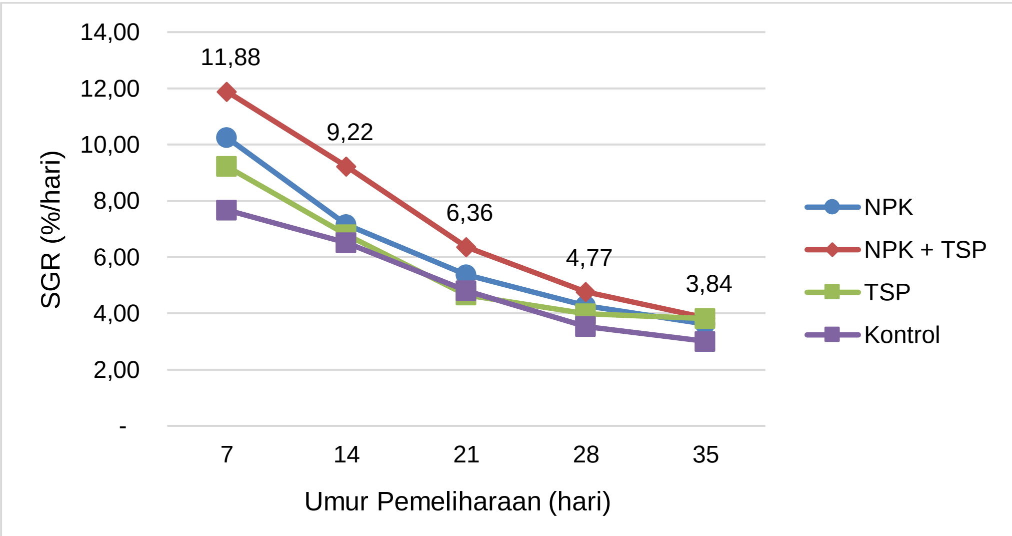

Fig. 4. Spesific growth rate of *K. alvarezii* at each culture period

The obtained SGR results varied throughout the growth period, with each seaweed sample depicting a declining trend. The decrease in specific growth rate is likely attributed to the rapid occurrence of cell division saturation. Seaweeds that have undergone adaptation to nutrient absorption from both fertilizer soaking and no soaking treatments experience a rapid growth phase, followed by a decrease in cell growth capacity, resulting in slow growth. This is supported by the statement by Asni (2015) that seaweed growth will increase until a point where it ceases. This indicates that cell multiplication and enlargement have reached their maximum limit under optimum conditions, leading to slowed growth. Additionally, the SGR of seaweed is presumed to decrease due to nutrient depletion resulting from the fertilization process, indicating that nutrients have been utilized for growth. This can be observed from the decreasing trend in the SGR graph. It is suspected that by the fourth sampling, the nutrient reserves from fertilization have been diminished.

Based on the ANOVA analysis of the soaking treatments of seaweed using NPK fertilizer, a combination of NPK+TSP fertilizer, TSP fertilizer, and no fertilizer soaking, each treatment showed a significant difference ($p<0.05$) in SGR. The results were further supported by the Duncan multiple range test, which indicated that the best daily weight growth of seaweed was observed in Treatment B (NPK+TSP), which significantly differed ($p<0.05$) from Treatments A (NPK), C (TSP), and D (no fertilizer). The lowest average weight growth was observed in Treatment D (no fertilizer).

From the smallest significant difference (Duncan test), there was a significant difference in SGR between the NPK+TSP treatment and the NPK treatment. However, there was no significant difference between the TSP treatment and the control group. This is evident in the graph, where the SGR graph for the TSP treatment overlaps with the control group. This suggests that the SGR between the control group and the TSP treatment is not significantly different. It is speculated that the growth of TSP-treated seaweed tends to be slow because the soaking with TSP does not contain nutrients such as nitrogen. This results in nitrogen being solely obtained from the water, where the nitrogen content is limited. Therefore, the growth of seaweed is hindered.

3.3. Morphology of K. alvarezii

3.3.1. Thallus length

The observation of thallus length growth was conducted by measuring the length of the main thallus. The average length of thallus at the initial seeding or the first observation ranged from 7.2 cm to 7.4 cm. From the second observation until harvest, the thallus length tended to increase. In the sixth observation, the treatments showed longer main thallus lengths, with NPK + TSP treatment recording 9.2 cm, NPK treatment recording 8.9 cm, TSP treatment recording 8.5 cm, and the control treatment recording 8.0 cm. The growth of main thallus length at each observation is presented in Fig. 5.

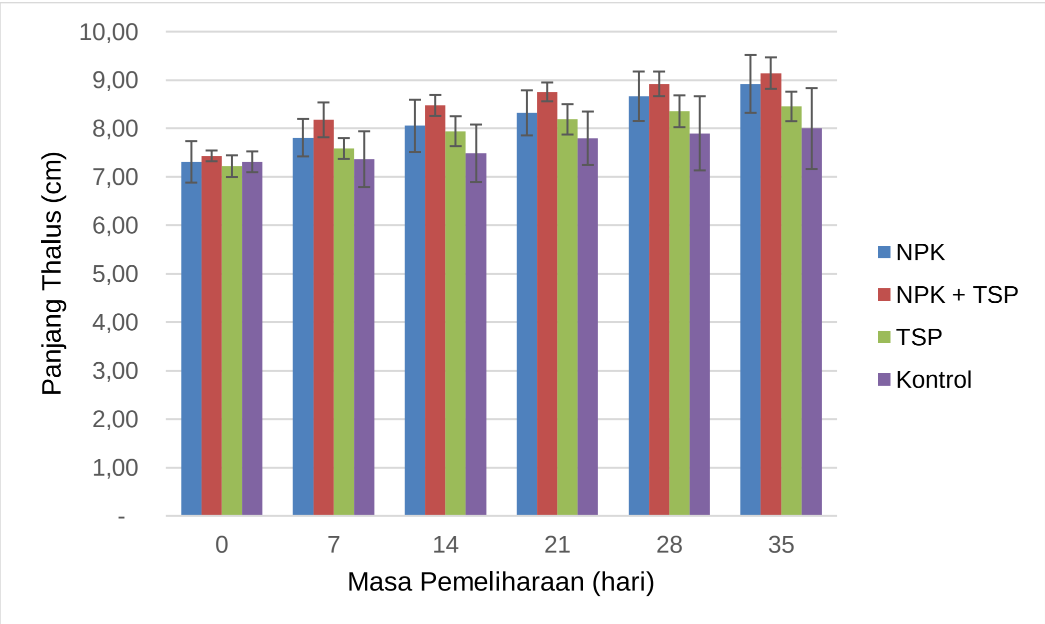

Fig 5. Length *of K. alvarezii*

From the measurement of the main thallus length in the first week, there was an acceleration in growth. The growth continued to be rapid until the fourth week and tended to slow down in each treatment by the fifth week. The elongation of thallus length in seaweed showed a rapid growth with an increasing trend. The increased growth of thallus length indicates that the seaweed has entered the cell elongation stage, facilitated by the availability of sufficient nutrients for growth. This is related to the role of phosphate as a nutrient source for seaweed growth. Phosphate is easily decomposed and absorbed by plants, stimulating the acceleration of thallus growth and the strengthening of young thalli into mature thalli. This is in line with the findings of Sari et al. (2012) that phosphate is a nutrient source capable of promoting thallus elongation. However, in the last observation week, the slowdown in the growth of the main thallus length is believed to be due to the thalli reaching their maximum length. The growth of seaweed tends to focus on expanding and multiplying new thalli on the main thallus branches, leading to more pronounced changes in weight rather than thallus length. This is consistent with the statement by Salisbury and Ross (1992) that young tissue growth is directed towards cell division and enlargement.

The differences in thallus length growth among treatments are likely due to the use of different soaking treatments with various fertilizers, where nutrients can be absorbed by the thalli and utilized for growth. One of the nutrients that can promote thallus elongation is phosphate. The results of phosphate content analysis for each fertilizer treatment, the phosphate content analysis results for each fertilizer treatment were as follows: NPK fertilizer had a phosphate content of 2.2 mg L^{-1}, NPK+TSP fertilizer had a phosphate content of 3.4 mg L^{-1}, and TSP fertilizer had a phosphate content of 0.62 mg L^{-1}.

The analysis of phosphate content in the fertilizers used as treatments indicates that the soaking treatment using NPK + TSP fertilizer had the highest phosphate content, at 3.4 mg/l, followed by NPK treatment at 2.2 mg/l, and TSP treatment at 0.62 mg/l. This is supported by the thallus length growth obtained during the study, with the highest thallus length recorded in the NPK + TSP soaking treatment, followed by NPK soaking and TSP soaking, while the control treatment without soaking showed the lowest thallus length growth. This is because the nutrients received by the seaweed thalli are obtained only from the surrounding water, where phosphate is a micronutrient with limited availability in the aquatic environment.

The analysis of variance (ANOVA) results for thallus length growth in response to the soaking treatments using NPK fertilizer, a combination of NPK + TSP fertilizer, TSP fertilizer, and the control treatment without soaking, showed no significant differences ($p<0.05$) in thallus length among the treatments, with a probability value of $0.64 > 0.05$. The ANOVA results can be found in Appendix 4.

According to the Duncan's multiple range test, the thallus length of the control treatment (without soaking) significantly differed from the thallus length of each soaking treatment. However, there was no significant difference in thallus length between the NPK and TSP soaking treatments, as well as between the NPK + TSP soaking treatment and the NPK, TSP, and control treatments. This is evident from the graph showing an increasing trend in the growth of the main thallus length, but with varying growth rates, which may be attributed to the pre-soaking treatment of the seaweed

3.3.2. Diameter of thallus

To observe the growth of thallus length, measurements were taken of the main thallus length. The average thallus diameter at the beginning of the cultivation or observation (first measurement) ranged from 5.70 to 5.77 mm. From the second observation until harvest, thallus length tended to increase. The best average diameter of the main thallus was obtained in the sixth observation for the NPK + TSP treatment (7.37 mm), followed by NPK (7.18 mm), TSP (7.11 mm), and the control (7.01 mm) treatment. The growth of the main thallus diameter for each observation can be seen in Fig. 6.

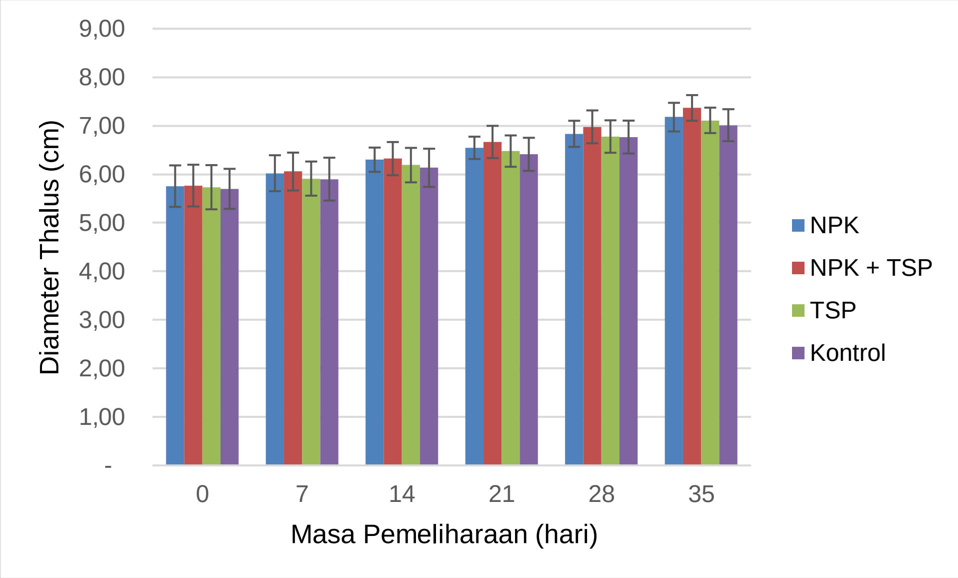

Fig. 6. Diameter of thallus

The measurements of the main thallus length in the first week showed growth, with accelerated growth observed in the fourth and fifth measurements. During the first week, the seaweed tended to focus on elongating the main thallus, which is consistent with the findings of Rozaki et al. (2013). At the beginning of cultivation, the cells of the seaweed were believed to focus on cell elongation, which is associated with the increase in the length of the main thallus. However, in the fifth and sixth weeks approaching harvest, the growth of seaweed diameter was relatively rapid. It is suggested that the cells of the seaweed distribute growth evenly between the weight of the seaweed and the expansion of the main thallus and branching. This results in a more pronounced change in weight compared to thallus length. This is in line with the statement by Kasim & Asnani (2016) that growth in the fourth week until harvest is predominantly directed towards weight and diameter increase in seaweed.

The differences in thallus diameter among the treatments are presumed to be influenced by the effects of fertilizer immersion. The nutrients that play a role in diameter enlargement are nitrogen and phosphate. Nitrate and phosphate are crucial for seaweed growth, with nitrogen being the primary limiting factor for its growth. Phosphate is also an essential nutrient in the formation of biomolecules such as amino acids, proteins, and phospholipids. Moreover, it plays a vital role in energy transfer facilitated by ATP and other high-energy compounds in photosynthesis and respiration processes. High phosphate levels can stimulate seaweed growth rate and increase carrageenan production (Martins et al., 2011).

Based on the phosphate content analysis of each fertilizer treatment, the highest phosphate content was found in the NPK+TSP fertilizer (3.4 mg/L), followed by NPK fertilizer (2.2 mg/L), and TSP fertilizer (0.62 mg/L). As for nitrogen content in each fertilizer, it is indicated on the fertilizer packaging. The NPK fertilizer contains 15% nitrogen, while the TSP fertilizer does not contain nitrogen but has phosphate content. This phosphate content in the TSP fertilizer contributes to the superior thallus diameter in the TSP fertilizer treatment compared to the control (without immersion). The faster growth of thallus diameter in the NPK+TSP treatment suggests that the combination fertilizer provides a more complete range of nutrients and promotes thallus diameter growth, followed by the NPK treatment, which contains sufficient nutrients for thallus diameter development.

The analysis of variance (ANOVA) results for thallus diameter in relation to the immersion treatment of seaweed using NPK fertilizer, the combination of NPK+TSP fertilizer, TSP fertilizer, and the control (without fertilizer immersion) showed no significant differences ($p<0.05$) with a probability value of 0.915 > 0.05 for thallus length. Further analysis was conducted using the Duncan multiple range test to determine the smallest significant differences among the treatments regarding the diameter of the main seaweed thallus.

According to the Duncan's test for the smallest significant differences, there were no significant differences in the diameter of the seaweed thallus between each treatment and the control. Therefore, the increase in weight is presumed to be caused by the elongation of the thallus length and the dense branching of the thallus. The visual differences in the seaweed samples for each treatment can be observed in Figure 7.

Fig 7. Seaweed growth: (a) Sampling 1 (7 days), (b) Sampling 2 (14 days), (c) Sampling 3 (21 days), (d) Sampling 4 (28 days)

The visual observations of the seaweed samples at each sampling point revealed distinct differences. Between Sampling 1 and Sampling 2, there was a noticeable difference in length. In contrast, both Sampling 3 and Sampling 4 exhibited denser growth patterns. The increase in weight is presumed to be a result of thallus elongation and the proliferation of branches in each seaweed sample.

3.3.3. Absolute growth

The seaweed cultivation process was carried out until 35 days of cultivation, and the average weight growth of seaweed was obtained for each treatment. The harvested seaweed was then weighed, and the percentage of final seaweed growth can be seen in Figure 8.

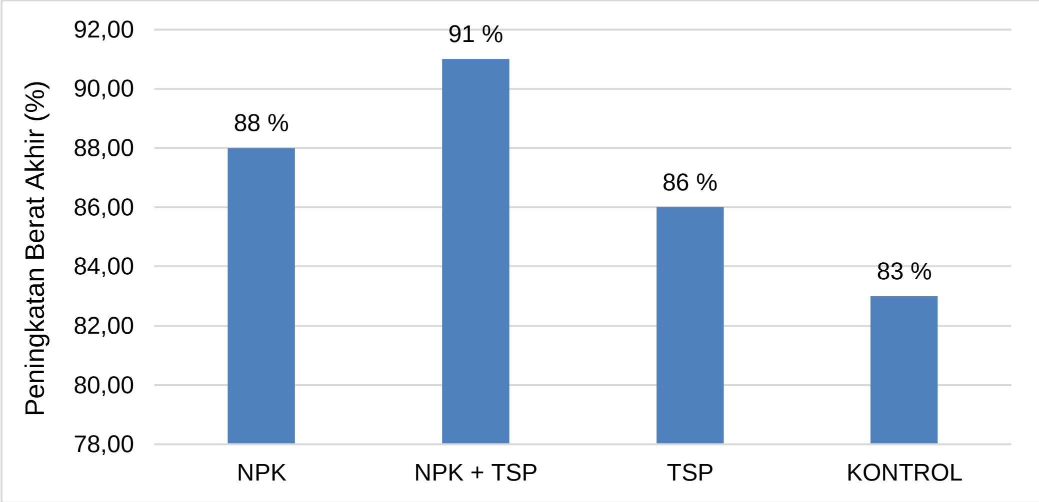

Fig.8. Absolute growth of *K. alvarezii*

The average harvest yield was obtained for each seaweed seedling stocking of 25 grams. The highest harvest growth was recorded in the NPK+TSP treatment (312 grams), followed by NPK treatment (214 grams), TSP treatment (183 grams), and the Control group (149 grams; 83%). These results demonstrate that the NPK+TSP treatment outperformed other treatments in terms of harvest yield. The percentage of growth from the initial stocking for each treatment was NPK+TSP (91%), NPK (88%), and TSP (86%).

4. Conclusion

The immersion treatment of seaweed using NPK and TSP fertilizers, as well as the combined immersion treatment of NPK+TSP, significantly influenced the absolute weight, with the following respective average absolute weights for the best treatments: NPK+TSP (57.48 g), NPK (37.80 g), TSP (31.69 g), and Control (24.844 g). The immersion treatment also had a significant effect on specific growth rate (SGR). However, in the post-hoc analysis using Duncan's test, the TSP treatment did not show a significant difference compared to the Control, with the following respective average SGRs for the best treatments: NPK+TSP (7.21%), NPK (6.13%), TSP (5.69%), and Control (5.10%). However, the immersion treatment of seaweed using NPK and TSP fertilizers, as well as the combined immersion treatment of NPK+TSP, did not have a significant effect on length and diameter.

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