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Effect of stocking density on growth performance of African catfish *Clarias gariepinus* and water spinach *Ipomoea aquatica* in aquaponics systems with the addition of AB mix nutrients

Pengaruh padat tebar pada kinerja pertumbuhan ikan lele *Clarias* sp. dan kangkung air pada sistem akuaponik dengan penambahan nutrien AB mix

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ABSTRACT

Aquaponics is the cultivation of fish and plants in a series of systems, either in one container or in separate containers, by paying attention to the balance between fish, plants, and aquatic microorganisms. One of the obstacles in aquaponic activities is that vegetable growth is not optimal due to a lack of dissolved nutrients, so further research is needed to make better plant growth. This study aimed to evaluate catfish and water spinach growth performance in an aquaponic system by adding AB mix nutrients at different fish stocking densities. This study used a completely randomized design with three differences in stocking densities of catfish (150 fish/m^3, 200 fish/m^3, and 250 fish/m^3) as test animals with four replications where AB mix was added to each treatment. The growth performance of catfish is better in control with a stocking density of 250 fish/m^3 and without adding nutrients. The growth performance of catfish decreased with the addition of AB mix nutrients, while the growth of water spinach was better. The growth rate of catfish without adding AB mix nutrients was higher than in other treatments. In contrast, all treatments with the addition of AB mix increased the growth performance of water spinach, with the stocking density of catfish not affecting the growth of water spinach plants.

Keywords: aquaponics, water spinach, catfish, growth

ABSTRAK

Akuaponik merupakan budidaya ikan dan tanaman dalam satu rangkaian sistem, baik dalam satu wadah maupun dalam wadah terpisah dengan memperhatikan keseimbangan antara ikan, tanaman dan mikroorganisme perairan. Salah satu kendala sistem akuaponik adalah pertumbuhan sayuran yang tidak optimal karena kurangnya nutrisi terlarut. Tujuan dari penelitian ini untuk mengevaluasi performa pertumbuhan lele dan kangkung dalam sistem akuaponik dengan penambahan nutrisi AB mix dan pada padat tebar ikan yang berbeda. Penelitian menggunakan rancangan acak lengkap dengan tiga perbedaan padat tebar ikan lele (150 ekor/m^3, 200 ekor/m^3, dan 250 ekor/m^3) sebagai hewan uji sebanyak empat ulangan di mana nutrien AB mix ditambahkan disetiap perlakuan. Kinerja pertumbuhan ikan lele lebih baik pada perlakuan kontrol dengan padat tebar 250 ekor/m^3 dan tanpa penambahan nutrisi AB mix. Performa pertumbuhan ikan lele menurun dengan adanya penambahan nutrisi AB mix, sedangkan pertumbuhan tanaman kangkung lebih baik. Laju pertumbuhan ikan lele dengan tanpa penambahan nutrisi AB mix lebih tinggi dibandingkan perlakuan lainnya, sedangkan semua perlakuan dengan penambahan AB mix meningkatkan performa pertumbuhan tanaman kangkung dengan jumlah padat tebar ikan lele tidak berpengaruh pada pertumbuhan tanaman kangkung.

Kata kunci: akuaponik, kangkung, lele, pertumbuhan

INTRODUCTION

Aquaponics is a combined system between aquaculture and hydroponics, namely by culturing fish in specific containers with the waste produced being used by plants (Maucieri *et al*., 2018; Maucieri *et al*., 2019). Plants that are generally used are vegetables in a cultivation container or a separate container using a pump (Lennard & Goddek, 2019; Baßmann *et al*., 2020). Aquaponics also considers the balance between fish, plants, and aquatic microorganisms (Eck *et al*., 2019) in the recirculation system. Plants can absorb the results of cultivation waste in the form of NH_3 or from the results of the decomposition of NH_3, feces and leftover feed to become NO_3 (Lam *et al*., 2015; Wongkiew *et al*., 2017). Aquaponics is more efficient and environmentally friendly because with this system, there is less change in cultivation water and plants do not require external fertilizers and only utilize cultivation waste (Goddek *et al*., 2015).

Aquaponics is also a solution to various sustainability issues, such as limited water availability, environmental pollution, fertilizer costs, and decreased soil fertility (Yep & Zheng, 2019). As a system that continues to develop and is increasingly popular (Wongkiew *et al*., 2017), both at the industrial and research scales (Yep & Zheng, 2019), this system needs to continue to be developed following technological developments. The sustainability of food products such as vegetables and protein sources can continue in urban environments (Pérez-Urrestarazu *et al*., 2019), where limited land is one of the challenges. As a system, aquaponics is relatively easy to implement, however, to get an ideal system, it needs further research.

The ideal aquaponics system is when the growth of fish and vegetables planted can be maximized and easy to operate (Andriani *et al*., 2017). In this modern era, to facilitate operations, it is necessary to have a technology application in the form of system innovation so that users can easily operate it. In addition to the ratio of stocking density of plants and fish that must be considered (Andriani *et al*., 2017), the productivity of fish reared by increasing the stocking density but with the amount of waste produced not exceeding system capacity is a challenge for the development of aquaponics (Palm *et al*., 2018). Furthermore, one of the obstacles in aquaponic activities is that vegetable growth is not optimal due to a lack of dissolved nutrients (Rakocy *et al*., 2004; Yep & Zheng, 2019), so t further research is needed to make better plant growth.

One way that has been developed to increase the availability of nutrients in water is the use of microbes (Yep & Zheng, 2019), and it is known that several types of microbes can improve plant growth and health (Eck *et al*., 2019). One of the nutrients used for the hydroponic system is AB mix nutrition which can provide good growth in spinach plants, pakchoi, and lettuce (Nugraha & Susila, 2015). More than that, environmental aspects must be a concern in using nutrients in the water (Singh & Dunn, 2016), especially for fish that are kept. This study aimed to evaluate the growth performance of catfish and kale in an aquaponic system by adding AB mix nutrients at different fish stocking densities.

MATERIALS AND METHODS

Materials

The fish used for this research were *Clarias* sp. Catfish originated from the Bogor hatchery with an average weight of 29.50 ± 0.20 g and an average length of 12.65 ± 0.18 cm. Furthermore, the fish were kept for one week for adaptation in the laboratory before being used for research for one month.

Experimental design

In this study, the treatment to be tested was the stocking density ratio of catfish and water spinach *Ipomoea aquatic*, which was suitable for the aquaponics system. The stocking density of catfish used was 150 fish /m^3, 200 fish/m^3, and 250 fish/m^3 with the same number of water spinach plants, namely seven water spinach plants in each treatment. Each tank will be controlled automatically based on the electrolyte conductivity (EC) readings to provide nutrients (Trejo-Téllez & Gómez-Merino, 2012) for water spinach plants.

Fish culture

Fish were reared using 16 tanks with a capacity of 80 L. Feeding was conducted as much as 4% of body weight with a frequency of three times a day. The amount of feed consumed and the number and weight of dead fish calculated and weighed. The amount of feed given is also adjusted to the weight of the fish based on the sampling results, which are carried out every week. Checking for dead fish is carried out during the maintenance period, both during feeding and sampling. Fish that died during rearing were seen on the surface, while fish that died on the bottom would also caught during sampling. The number of dead fish is weighed directly. Each unit of the maintenance container is equipped with an aeration system to maintain good water quality.

Fish growth performance

Observation parameters include production parameters. Production parameters include survival rate (SR), total feed consumption (JKP), feed consumption ratio (FCR), average body weight (ABW), specific growth rate (SGR), biomass, and productivity (Haliyani, 2021; Deswati *et al*., 2023).

Water quality parameters

Water quality measurements include physical and chemical parameters of water, namely pH measurements and dissolved oxygen (DO), which are carried out daily. pH measurement was done using a pH meter (pH Meter Trans, Senz pH). Dissolved oxygen was measured using a DO meter (Lutron DO-5510).

Growth plant parameters

Observation parameters for water spinach plants include plant height, number of leaves, and harvest weight (stalk weights, root weights, total weights, and ratio of stalk and root) (Göthberg *et al*., 2004; Khairunisa *et al*., 2022).

Data analysis

This study was designed using a completely randomized design (CRD) with four replications. The data obtained were analyzed using analysis of variance with a confidence level of 95%. Then a different t-test was carried out using the Duncan test.

RESULTS AND DISCUSSION

Result

Water quality

The water quality parameter in the form of pH value shows relatively the same conditions between treatments, ranging from 6.71-8.26 (Figure 1). The pH value tends to decrease throughout fish raising. The pH value between the treatments showed no difference, with the mean value being 7.40 ± 0.03.

Dissolved oxygen during fish rearing is shown in Figure 2. The value of dissolved oxygen (DO) decreases along with the fish-rearing period. High

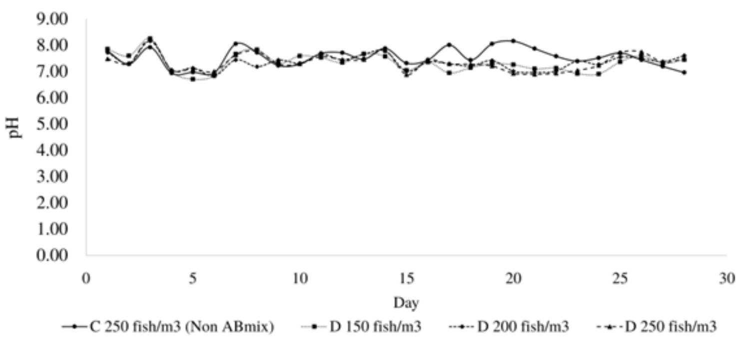

Figure 1. The pH value of *Clarias* sp. rearing water at various levels of stocking density with the aquaponics system for 28 days.

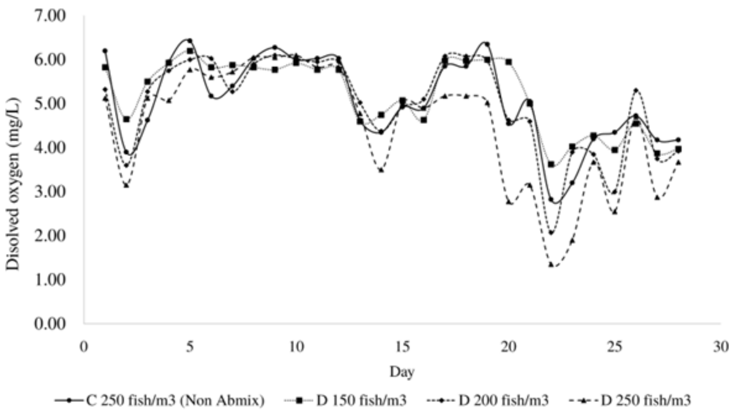

Figure 2. Dissolved oxygen value of *Clarias* sp. Catfish culture media at various levels of stocking density with the aquaponics system for 28 days.

fish density (250 fish/m^3) indicates a low average DO value, 4.49 ± 0.26 mg/L, compared to control and other treatments (Figure 2). Water quality parameters during the rearing period of fish in the aquaponics system experienced a decrease in dissolved oxygen at high stocking densities with the addition of nutrients.

Fish growth performance

The amount of feed consumption in control (without added nutrition) was higher than the treatment with the same stocking density and when compared to other treatments. The highest amount of feed consumption was 631.75 ± 18.97 g in the nutrient-free treatment (Table 1). The growth parameters of catfish include food consumption ratio (FCR), specific growth rate (SGR), and biomass showing the difference between treatments except for the survival parameter (SR) (Table 1). The growth performance of catfish is better in control with a stocking density of 250 fish/m^3 and without adding nutrients. The growth rate reached 2.18 ± 0.18, FCR value of 1.22 ± 0.17, biomass 1100.00 ± 57.44 g, and productivity was 13.75 ± 0.72 kg/m^3.

Plant growth performances

Plant height

Fish density did not affect *Ipomoea aquatica* height. However, in treatment A, with a fish density of 150 fishes/m^3, and treatment B, with a fish density of 200 fishes/m^3, water spinach plants tended to be higher than in treatment C, with a fish density of 250 fishes/m^3. The addition of AB mix more influenced the height of the water spinach plants; the size of the water spinach plants in the AB mix treatment was more significant than that of the control (Figure 3).

Table 1. Growth parameters of *Clarias* sp. catfish during the maintenance period of 28 days in aquaponic systems with different stocking densities.

Parameter	Treatment			
	C 250/m^3 (Non AB mix)	D 150/m^3	D 200/m^3	D 250/m^3
JKP (g)	631.75 ± 18.97^c	411.25 ± 17.36^a	395.00 ± 21.31^a	515.00 ±17.32^b
SR (%)	88.75 ± 4.27^a	75.00 ± 6.80^a	76.56 ± 8.22^a	83.33 ± 2.89^a
FCR	1.22 ± 0.17^a	1.95 ± 0.20^{ab}	2.99 ± 0.55^b	2.42 ± 0.44^b
SGR (%/day)	2.18 ± 0.18^b	1.75 ± 0.16^b	1.02 ± 0.19^a	0.92 ± 0.04^a
ABW (g)	62.16 ± 3.00^b	55.25 ± 2.42^b	45.24 ± 2.44^a	43.77 ± 0.64^a
Biomass (g)	1100.00 ± 57.44^c	493.75 ± 36.99^a	554.75 ± 68.90^{ab}	730.00 ± 31.22^b
Productivity (kg/m^3)	13.75 ± 0.72^c	6.17 ± 0.46^a	6.93 ± 0.86^a	7.06 ± 2.09^b

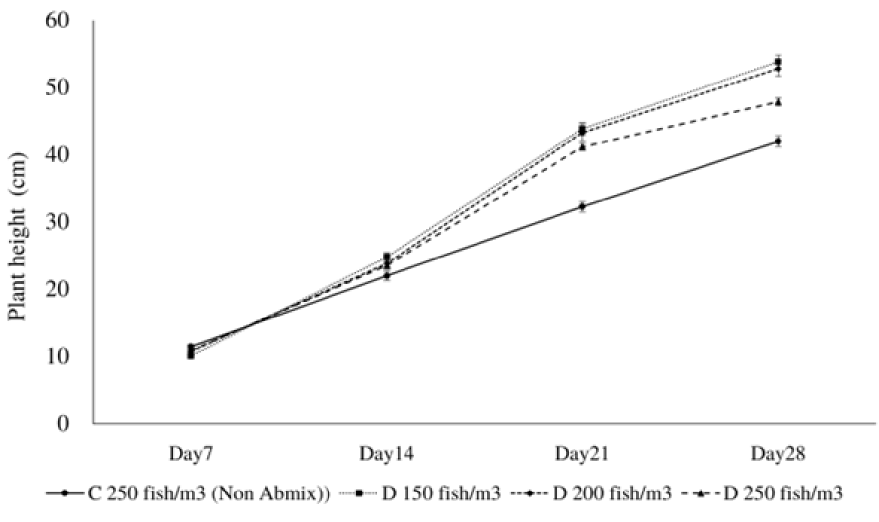

Figure 3. High of water spinach *Ipomoea aquatica* at various fish stocking density with the aquaponics system for 28 days.

Number of leaves

The same results were also shown in the number of leaves. The density of catfish only had a significant effect on the number of water spinach leaves one week after planting (1WAP). The rest during the growth period, the three treatments of catfish density did not significantly affect on the number of leaves of water spinach plants (Figure 4).

Water spinach harvest

The fish density treatment also had no significant effect on the harvest variables, crown weight, root weight, total weight, and stalk:root ratio. However, the control treatment without adding AB mix nutrients had lower yields than the aquaponic treatment, which received additional AB mix nutrients (Figure 5).

Discussion

The pH value is still appropriate for the life needs of catfish following the Indonesian National Standard Number 6484.3: 2014, with the optimal pH value for catfish, is in the pH value range of 7.5 (Phuoc *et al.,* 2020). This parameter is the main thing that is often monitored in fish farming because the pH value will affect chemical processes in the waters, so if there is a drastic change, it can cause stress to fish to death (Zibiene & Zibas, 2019). In addition to affecting the condition of the fish, the pH value is also a concern in nutrient management for hydroponic activity (Singh & Dunn, 2016). The results of pH measurements show that the pH value is slightly higher for spinach even though these conditions are ideal for fish. According to Singh and Dunn (2016), the outstanding pH value for plant roots is 6-7, at which pH value nutrients are more available to plants.

An increase in cultivation time affects a reduction in water quality, including the value of DO (Zibiene & Zibas, 2019). This can be caused during the cultivation and growth of fish, the amount of feed consumption increases and the accumulation of metabolic waste occurs. According to Liu *et al*. (2016), the decreased

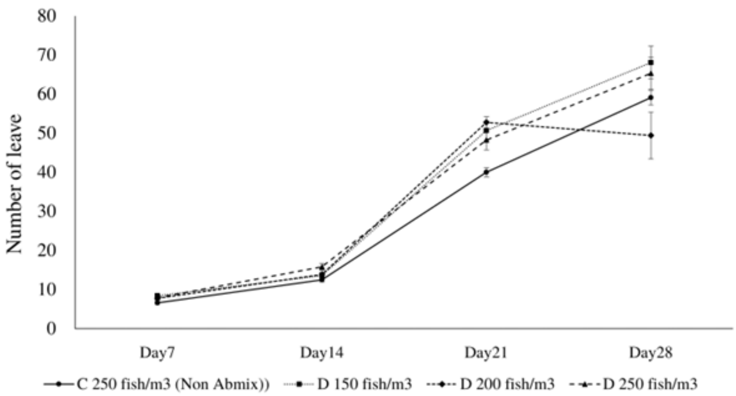

Figure 4. Number of leave-water spinach *Ipomoea aquatica* at various fish stocking densities with the aquaponics system for 28 days.

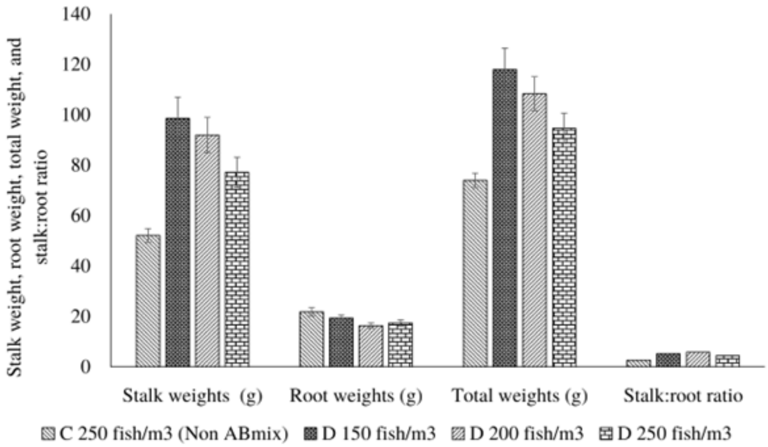

Figure 5. Stalk weights, root weights, total weight, and the ratio of stalk and root at the harvest time of *Ipomoea aquatic* at various fish stocking densities with the aquaponics system for 28 days.

dissolved oxygen can be caused by increased stocking density. Other water quality parameters, such as temperature, showed the same values between treatments. According to Liu *et al.* (2016), fish stocking density affects FCR, body weight, standard length, and condition factor.

Catfish are suspected to be sensitive to adding fertilizer at concentrations between 1-1.5 µS/Cm. Nutrition is thought to cause stress in fish which results in a decrease in fish appetite. The decline in growth can also be caused by the stocking density, where the specific growth rate decreases with an increase in the stocking density. This study's results align with the research by Liu *et al.* (2016). Another factor affecting the growth of fish and plants in an aquaponic system is the water recirculation rate.

Based on the results of the experiment by Diem *et al.* (2017), a high-water recirculation rate (200-400%) per day is required to ensure proper growth of tilapia at high densities (114-125 fish/m^3). High water recirculation rates also improve water quality. In addition, adding a gravel filter before water is channelled into the hydroponic bed can increase nitrification and increase particle transfer in the aquaponic system. Moreover, achieving sustainable aquaponic production requires a balance between nutrient concentration and pH for optimal growth of fish, plants, and nitrifying bacteria. The addition of nutrients increased the growth performance of water spinach plants.

In the aquaponic treatment without adding AB mix nutrition, the EC value was approximately 0.4 mS/cm. This value indicates that the nutrients in the water pool are insufficient for the maximum growth and development of water spinach plants. Plants require complete nutrition to support their growth and development, and adding AB mix nutrients can improve water spinach plants' growth and product performance. AB mix nutrition contains both macro and micronutrients needed by plants, and a deficiency of these essential nutrients will reduce plant growth and development (Harahap *et al.*, 2020).

Water spinach can grow and develop well even at the lowest density of catfish. This is in line with research by Maucieri *et al.* (2020), where the best growth is in aquaponic treatment at low densities. There is integration between fish and plants at one time; it is hoped that there is no need to add nutrients from the outside. This condition is different from the research conducted by Harahap *et al.* (2020) in that adding AB mix nutrients can affect the number of leaves. This difference may be due to differences in the concentrations given.

The three treatments received the same extra nutrients with EC values ranging from 1-1.5 mS/cm. This EC value is within the ideal range for water spinach growth, which is between 1.8-2.3 mS/cm (Singh & Dunn, 2016). Ideal EC conditions also affect the presence of nutrients and the water's pH value (Singh & Dunn, 2016). The primary nutrients needed by plants are nitrogen and phosphorus. In an aquaponic system, nitrogen from fishpond water is used as a source of nutrition for plants.

Understanding nitrogen transformation in aquaponic cultivation is a critical requirement for increasing the efficiency of nitrogen use by plants. The processes of nitrification and denitrification that occur continuously in pond water cause a high loss of nitrogen. The loss was affected by the low oxygen level in the water (DO). Based on the results of studies on nitrogen loss in aquaponic systems, nitrogen loss from aquaponic systems in N_2O gas can reach 0.72-1.03% of the existing nitrogen input. To overcome this problem, a biofilter aerator can be used to prevent the formation of anoxic zones from reducing nitrogen loss.

N_2O gas emissions from aquaponic systems can also be reduced by increasing the plant: fish ratio cultivated. Based on the experimental results of Paudel (2020) , the plant: fish density ratio at higher aquaponic production has a higher nitrogen absorption value by plants, which is ~56 mg/day in hydroponic beds and reduces N_2O emissions, which are lower by 17% compared to control treatment. The experimental results of Nuwansi *et al.* (2021) show that the use of phytoremediation aquaculture wastewater can supply nutritional needs and add bacterial colonies to the aquaponic system so that the provision of phytoremediation aquaculture wastewater in freshwater can be used effectively to increase aquaponic productivity with high density in fish and their plants.

CONCLUSION

The growth performance of catfish is better in control with a stocking density of 250 fish/m^3 and without adding nutrients. All treatments with the addition of AB mix increased the growth performance of water spinach, with the stocking density of catfish not affecting the growth of water spinach plants.

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