N, P and K content in non-soil planting media for pakchoy (*Brassica rapa* L.) cultivation in vertical circulation system of aquaponics

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Abstract. This study attempts to integrate freshwater fish aquaculture with vegetable cultivation by using agricultural waste as planting media. It is expected that environment friendly technology will be developed for integration of pak choy cultivation and freshwater catfish production (*Clarias* sp.). The aims of the study are to determine the types of organic planting media and aquaponics watering system that is able to provide sufficient nutrients to the integrated agriculture system. Four organic materials from agricultural wastes e.g. shavings woods, coconut husk, coconut shell biochar and coffee shell biochar were used for growing media. Two aquaponic watering systems with catfish rearing were combined with the organic materials as planting media in a factorial randomized block design of experiment. Addition of organic materials into growing media of pak choy is necessary in the aquaponic system because besides make the media better texture, they also provide nutrients to the plant, particularly the phosphorus. Between the organic materials, coconut shell biochar was high content in phosphorus, while coffee shell biochar in potassium. The experiment also concluded that water circulation has no effect on the nutrition concentration in the aquaponic system.

1. Introduction

Many factors affect the growth of plants, one of them is combination and concentration of mineral nutrients availability in soil. Incidents of deficiency occur quite often led to a decrease of plant productivity and quality [1]. At the same time, the availability of arable land becomes more difficult due to land use change. Look at these factors, it is necessary to develop alternative media not based on soil and integrate it with other activities that can improve space productivity.

An integrated agriculture system might combine several business units which are managed in an integrated, ecologically oriented, in order to obtain an increase of economic value. Integrated agriculture provides synergy between environmental sustainability with economic aspects through high efficiency, effectiveness and productivity values [2].

An integrated plant cultivation with freshwater aquaculture, for instance, is able to increase efficiency in agricultural practices and is also economically profitable. It has been applied in an aquaponic system where vegetable cultivation is combined with fish rearing. Aquaponics is a concept relatively new to modern food production methods and might contribute to food security because it provides carbohydrate and healthy protein at the same time, promising the best alternatives for achieving economic and environmental sustainability [3], [4]. Aquaponic does not require soil and promotes utilization of
agricultural waste as planting media. Utilization of freshwater fish cultivation and agricultural wastes can be an alternative in increasing vegetable production [5].

This study attempts to integrate freshwater fish aquaculture with vegetable cultivation by using agricultural waste as planting media. It is expected that environmental friendly technology will be developed for integration of pakchoy cultivation and freshwater catfish production (Clarias sp.). The aims of the study are to determine the types of organic planting media and aquaponics watering system that is able to provide sufficient nutrients to the integrated agriculture system.

2. Materials and methods

2.1. Biochar Production
Shells of coconut and coffee were used as material for biochar production. The shells were burned in a Kon-Tiki (Figure 1) for around 1.5 hours. The combustion was ended by watering the Kon-Tiki when the shell had turned completely black. Then, the wet biochar was dried under the sun.

![Figure 1. A kon-tiki to produce biochar.](image1)

2.2. Nursery and preparation of growing media
Pakchoy seeds were sown in a nursery for 28 days in a growing pot with a media consisting of a mixture of soil and cow manure with a ratio of 2 : 1, 20 grams of a mixture of wood shaving and coconut husk, as well as 100 g of biochar. Five pots were arranged in an aquaponic bucket where one third of the pot laid under water. Pakchoy was harvested 8 weeks after planting.

2.3. Vertical aquaponic system
Aquaponic bucket was filled with 30 liters of fresh water. Probiotic bacteria (10 cc l⁻¹) and dolomite (4 g l⁻¹) were added into the bucket. Four days after bucket preparation, five catfishes were reared in each bucket. Totally 24 aquaponic buckets were used in this experiment.

![Figure 2. Vertical circulation system of aquaponic.](image2)
2.4. Experimental design
Factorial randomized block design with 3 replications was employed in this experiment. The first factors were the type of organic materials added into growing media consisting of wood shavings (B1); coconut husk (B2); coconut shell biochar (B3); and coffee shell biochar (B4). The second factors were an aquaponic circulation system consisting of uncirculated water (L1); and vertical water circulation with a single L pipe (L2). Macro nutrients such as N, P and K in the circulation system were analysed before treatments and after plant harvest.

3. Results and discussion

3.1. Effect of addition of organic materials to the nutrient content of growing media
Table 1 showed the N, P, and K content of the materials used as additives in the growing media. The materials had high content of K, followed by N and P. According to [6], utilisation of those materials in the growing media still needs additional N, P and K.

| Material                      | Moisture content (%) | N (%) | P (%) | K (%) |
|-------------------------------|----------------------|-------|-------|-------|
| Wood shavings waste           | 8.06                 | 0.44  | 0.01  | 0.23  |
| Coconut husk                  | 12.93                | 0.71  | 0.02  | 1.03  |
| Coconut shell biochar         | 11.82                | 0.24  | 0.07  | 0.99  |
| Coffee shell biochar          | 8.65                 | 0.52  | 0.11  | 0.58  |

The experiment showed that the application of organic materials was able to significantly increase the nutrient content of particularly N and K, but P (Table 2). After addition of organic materials, the nutrient content of planting media improved where N ranged from 0.63-1.01%. The highest contributor for N was wood shaving waste followed by coconut husk and coffee shell biochar. Although addition of organic materials was able to improve N and K, planting media were still classified as deficient in nutrition according to Mengel and Kirkby [6].

The P contents of non-soil planting media ranged between 0.14 and 1.15% (Table 2). Planting media with the addition of coconut shell had the highest P content. Addition to organic materials into planting media is able to fulfil the requirement of P for optimal growing of pakchoy [6].

At the same time, the contents of K of mix planting media ranged from 0.59 to 1.11% (Table 2). The highest K content was observed in the plating media with coffee shell biochar as well as coconut shell biochar. However, the content of K in all planting media is still not enough for pakchoy growing [6].

Nutrient balance is the key component to increase crop yields. Excessive or imbalanced nutrients in the soil or media may cause negative effects on crop productivity and ultimately soil health [7].
3.2. Effect of aquaponic circulation system on nutrients content
The experiment showed that type of aquaponic circulation system had no effect on N, P and K contents of the aquaponic water (Table 3). P contents in both water circulation system ranged between 0.17-0.25% indicating sufficient amounts to support optimal growth of pakchoy. In contrast, N and K contents are below 1% in the water circulation system. Fertilizers are needed to improve the availability of N and K to best performance of pakchoy in the aquaponic system.

| Treatments                          | N (%)  | P (%)  | K (%)  |
|-------------------------------------|--------|--------|--------|
| Non-circulating water (L1)         | 0.83 a | 0.17 a | 0.85 a |
| Vertical water circulation (L2)     | 0.94 a | 0.25 a | 0.80 a |

* Letters in superscript indicate differences at 5% level

4. Conclusion
Addition of organic materials into growing media of pakchoy is necessary in the aquaponic system because besides making the media better texture, they also provide nutrients to the plant particularly the phosphorus. Between the organic materials, coconut shell biochar was high content in phosphorus, while coffee shell biochar in potassium. The experiment also concluded that water circulation has no effect on the nutrition concentration in the aquaponic system.

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