EVALUATING THE EFFECTIVENESS OF NEWLY DEVELOPED ORGANIC FERTILIZERS BY COMBINATION OF RICE HUSK BIOCHAR, SEAWEED AND PLANT RESIDUES ON MUSTARD GREENS (*Brassica juncea*)

Le Huu Quang*, Nguyen Hai Au

Institute for Environment and Resources, VNU-HCM

*Email: *lequang@wacc.edu.vn*

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ABSTRACT

This paper presents the results of research on the different combination of rice husk biochar (RHB), seaweed (SW) and composted plant residues (CPR) to produce two new organic fertilizers as well as evaluated their effectiveness on agronomic and economic efficiency on mustard greens. Through analysis of fertilizer quality criteria according to QCVN 01-189:2019/BNNPTNT, the above two fertilizer types meet the quality of organic fertilizers; The results of testing the agronomic effectiveness as well as the economic efficiency of two new organic fertilizers on mustard greens showed that with the dosage of 3000 kg/ha/crop, the yield increased to 10 tons/ha (21.4%) compared with the control in two separate ecological zones and two different soil types consisting of grey soil and mixed sandy soil. The results of this study show that the above two types of organic fertilizers obtained in this study can be applied to agricultural cultivation.

Keywords: Biochar, seaweed, organic fertilizer, rice husk, organic materials.

1. INTRODUCTION

For decades, agricultural soil has been degraded due to the excessive use of chemical fertilizers. More recently, modern agriculture has been returning to traditional cultivation through the increased application of organic fertilizers. These are derived from animal or plant matter, and their application can modify soil physicochemical conditions and biological properties, due to the abundance of organic matter and balancing of nutrient levels [1-3]. Many studies have shown that using organic fertilizers is effective way to improve soil fertility, crop yield, and environmental quality [4-6]. Currently, there are many organic materials are produced as by-products in agricultural activities such as RHB, SW, coconut fiber, and rice husk ash. Among these, RHB is produced from plant biomass by pyrolysis at a high temperature, in the absence or lack of oxygen [7] and biochar microstructure were formed under pyrolytic condition [8]. As RHB is highly stable and resistant to decomposition, it has the ability to affect the nitrifying microbial community, increasing the nitrogen fixation process. Because it is a substance with a high C/N ratio, RHB can also be used for long-term soil carbon sequestration, i.e., remaining buried in soil for hundreds of years [9]. Furthermore, the improvement of soil properties [10] and the enhancement of plant growth [11] can be achieved as a result of RHB addition to soil. SW extracts are commonly utilized as agricultural biostimulants in food production worldwide. These biostimulants possess several valuable properties for improved plant growth, yield, quality, and tolerance to abiotic and biotic stresses, as well as improving nutrient use [12, 13]. In this study, the effectiveness of organic fertilizers, by combining RHB, SW, and CPR was evaluated on mustard greens (*Brassica juncea*), a common and important vegetable in Vietnam.

2. MATERIALS AND METHODS

2.1. Materials

Different ratios of the main ingredients, consisting of composted plant residues (CPR), dried seaweed (SW), and rice husk biochar (RHB), were mixed to produce two organic fertilizer formulas (OFFs). Based on the nutrient content contained in the raw materials and the need for the ratio of nutrients of the newly created organic fertilizer. The first organic fertilizer formula (OFF1) included CPR, SW, and RHB at ratios of 68%, 20%, and 11%, respectively. The second organic fertilizer formula (OFF2) comprised CPR, SW and RHB at the ratios of 71%, 16%, and 12%, respectively. Both formulas were additionally supplemented with 1% mixed trace elements. *Trichoderma* sp. as effective microorganisms with trade name BIMA made by Biotechnology Center of HCM City were added to the OFFs at the rate of 4 kg/ton organic material. After mixing well fertilizers were incubated separately, covered with a nylon tarpaulin to retain moisture. The OFFs were watered weekly to maintain the moisture at 50 - 55% and mixed completely after three weeks. After 1.5 months of incubation, the completed organic fertilizers were investigated the effectiveness on the development of mustard greens. The experimental vegetable seeds were purchased from East - West Seed Co., ltd. Plant seedlings were grown with density of 250.000 plants/ha.

Fig. 1. Organic fertilizer mixture after mixing

2.2. Method of experimental design

Experiment consists of seven treatments, in which treatment 1 was used as control (composted cow dung with 15% organic matter, 1.57% N, 2.29% P_2O_5 and 1.08% K_2O). OFF1 was applied on treatments marked 2, 3, and 4, with dosages of 1000 kg/ha, 2000 kg/ha and 3000 kg/ha, respectively. OFF2 was applied on treatments marked 5, 6, and 7, with dosages of 1000 kg/ha, 2000 kg/ha and 3000 kg/ha, respectively. The fertilizer base is 80N + 40P_2O_5 + 40K_2O kg/ha, equivalent to 174 kg of Urea + 250 kg of super phosphate and 67 kg of potassium fertilizer. Both fertilizer formulas were also applied on the soil before sowing vegetable seeds.

Fig. 2. Experiment area

The experiment was arranged in a randomized complete block design (RCBD), the experimental plot area was 20 m^2, and repeated 3 times. The evaluation criteria included plant height (cm), at the harvesting stage, measured from close to the ground to the top of the plant's tallest leaf. For each replicate, data from 10 plants were taken and the average values of yield components and yields collected on the whole plot. The yields were compared to the control. The growth and development of the experimental plants were evaluated, including the degree of pest infestation (Record the type of pests and diseases that appear, the rate of damage) and the plants' ability to withstand adverse external conditions by sensory method.

2.3. Sample analysis

For the organic fertilizer, the nutrient content and physical properties were analyzed. The nutrient composition and limited composition were analyzed using the classical physiological method. Data processing was performed using Excel and Statgraphics Centurion XV software.

3. RESULTS AND DISCUSSION

3.1. Assessment the quality of newly created organic fertilizer

After incubation, two fertilizer formulas were tested for different physical and physicochemical parameters. The results are presented in Table 1.

Table 1. Physical and physicochemical characteristics of the organic fertilizers

Ingredients	Analytical methods	OFF1	OFF2
OM (%)	TCVN 9294:2012	45	43
Humic acid (%)	TCVN 8561:2010	1	1
Fulvic acid (%)	TCVN 8561:2010	0,5	0,5
N_{total} (%)	TCVN 10682:2015	2	2
$P_2O_{5\ available}$ (%)	TCVN 8559:2010	1	1
$K_2O_{available}$ (%)	TCVN 8560:2018	1	3
Humidity (%)	TCVN 9297:2012	30	30
pH (H_2O)	Ref. TCVN 5979:2007	5	5,5
$SiO_{2\ available}$ (%)	TCVN 11407:2019	1	1
Cu (ppm)	TCVN 9286:2018	50	50
Zn (ppm)	TCVN 9289:2012	300	250
Bo (ppm)	TCVN 10679:2015	100	150
Mn (ppm)	TCVN 9288:2012	50	50
Fe (ppm)	TCVN 9283:2018	50	50

The results show that the organic content reached up to 43 and 45% while the standard average for different types of organic fertilizer is 20% suggesting the effectiveness of the developed fertilizers because organic matter plays an important and multi-faceted role in soil. Physically, organic matter influences soil structure and all associated properties. Chemically, soil organic matter affects the cation exchange capacity and the capacity for buffering changes in soil pH [14]. In particular, the composition also contains humic and fulvic acids, which are beneficial elements for root development, increasing plants' ability to absorb nutrients. The beneficial effects of humic substances, such as biostimulants, on plant growth have been well known since the 1980s, and they can be supportive to a circular economy if extracted from different renewable resources of organic matter, including harvest residues, wastewater, sewage sludge, and manure [15]. Silica, a major constituent of rice husk biochar. Rice husk biochar includes a mixture of amorphous and crystalline forms of silica resembling cristobalite and tridymite. It provides a readily soluble form of both lime and plant nutrient elements so its use on acid, infertile soil should be encouraged. In both fertilizers, the RHB ratio is calculated to achieve a SiO_2 content of about 1%. In addition, some macronutrients and micronutrients essential for plants were detected at low quantity. The availability of micronutrients, such as iron, could be improved with humic acid, not only by chelation, but also by promoting the root capability to uptake nutrients from the soil solution [16]. With such diverse nutritional contents, the two fertilizers can meet the nutritional needs of plants, if applied at the right dose and at the right time.

To evaluate the safety of the fertilizers, the presence of heavy metals and pathogenic bacteria were examined and the results are shown in Table 2.

Table 2. Concentration of heavy metals and pathogenic bacteria in organic fertilizers

Concentration of limiting factors in organic fertilizers	Analytical methods	Vietnamese standard	OFF1	OFF2
Hg	TCVN 10676:2015	<2 ppm	1,0 ppm	1,0 ppm
Pb	TCVN 9290:2012	<200 ppm	10,0 ppm	10,0 ppm
As	TCVN 11403:2016	<10 ppm	1 ppm	1 ppm
Cd	TCVN 9291:2012	<12 ppm	1,0 ppm	1,0 ppm
E. coli	Ref. TCVN 6846:2007	1.1 x 10^3	1 x 10^3 CFU/g	1 x 10^3 CFU/g
Salmonella	Ref. TCVN 4829:2005	ND	ND	ND

There is increasing evidence that organic fertilizers can contain high concentrations of trace metals, such as chromium (Cr), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd), and lead (Pb). If organic fertilizers are applied to an agricultural area, some trace metals could accumulate on farm land, some of which could be transferred to humans [17]. Therefore, these factors must also be examined before their application on crops and soil. The results showed that when compared to allowable standards, heavy metals, such as mercury (Hg), As, Pb, Cd, and some harmful microorganisms such as *Escherichia coli* (*E. coli*) and *Salmonella*, were below the safety parameters for fertilizers. Thus, both newly-created fertilizers met the current regulations for use as crop fertilizers.

3.2. Experimental results of agronomic effectiveness on mustard greens

After the obtained fertilizers passed the safety tests, the evaluation of their effect on mustard greens was continued. The results in grey soils (acrisols) at Hoc Mon, Ho Chi Minh City are shown in Table 3.

Table 3. Experimental results on the effect of organic fertilizers on the growth of mustard greens grown on grey soils (acrisols).

Treatment	Plant weight (g)	Plant height (cm)	Yield (ton/ha)	Yield increasing (ton/ha)	Yield increase (%)
Season 1 (22/8/2020 – 30/9/2020)					
1	36.7^{a}	25.3^{a}	47.3^{a}		
2	41.0^{ab}	30.0^{ab}	48.0^{ab}	0.7	1.4
3	47.3^{bc}	33.0^{b}	51.0^{abc}	3.7	7.7
4	50.3^{c}	33.3^{b}	56.0^{c}	8.7	18.3
5	45.7^{bc}	31.3^{b}	50.7^{abc}	3.3	7.0
6	47.7^{bc}	33.0^{b}	53.0^{abc}	5.7	12.0
7	52.3^{c}	35.3^{b}	54.7^{bc}	7.3	15.5
CV%	13.8	12.7	8.9		
$LSD_{(0,05)}$	7.8	5.4	7.1		
Season 2 (1/11/2020 –29/11/2020)					
1	36.7^{a}	28.3^{a}	48.3^{a}		
2	42.7^{ab}	30.7^{ab}	51.0^{ab}	2.7	5.5
3	48.7^{bc}	33.3^{ab}	53.0^{ab}	4.7	9.7
4	53.7^{c}	34.3^{b}	54.3^{ab}	6.0	12.4
5	45.3^{abc}	30.3^{ab}	52.7^{ab}	4.3	9.0
6	46.0^{bc}	33.3^{ab}	53.0^{ab}	4.7	9.7
7	50.3^{bc}	36.0^{b}	56.7^{b}	8.3	17.2
CV%	14.5	11.6	7.2		
$LSD_{(0,05)}$	8.8	5.8	6.1		

(CV: Coefficient of variation, LSD: Least Significant Difference. Different letters show statistical different at $P < 0.05$).

Biologically, organic matter acts as the nutrient and energy supply for microbial biomass and higher plants. A soil which is biologically and chemically fertile, but which cannot physically support crop development, will not fulfill its agronomic potential. Soil productivity is, therefore, determined by a combination of the organic matter's influence on the physical, chemical, and biological properties. It has been shown that the incorporation of crop residues into soil is beneficial, improving one or more essential soil attributes [14]. The data showed that both fertilizers could improve yield components and increase yield of mustard greens, compared to the control. Hence, from the increase of the above yield components, the yield of mustard greens in season 1 increased from 1.4 to 18.3% compared to the control, and in season 2 increased from 5.5 to 17.2% compared to the control. In the formulas that were supplemented with fertilizer, the plants grew quickly, and the leaves and stems were larger than the control. At the harvest time, the average price of vegetables is 5,000 VND/kg, the price of experimental organic fertilizer is expected to be 2,500 VND/kg, and the labor cost of fertilizing is 500,000 VND/ha. Thus, after deducting costs incurred from organic fertilizers, the net profit is from 500,000 - 35,500,000 VND/ha/crop.

In addition, the fertilizers were tested on sandy soil type in Thu Duc city, Ho Chi Minh City. The results are shown in Table 4.

Table 4. Experimental results on the effect of organic fertilizers on the growth of mustard greens grown on sandy soil.

Treament	Plant weight (g)	Plant height (cm)	Yield (ton/ha)	Yield increasing (ton/ha)	Yield increase (%)
Season 1 (22/8/2020 – 30/9/2020)					
1	37.7[a]	27.0[a]	46.7[a]		
2	44.7[ab]	28.7[ab]	50.7[ab]	4.0	8.6
3	47.7[bcd]	33.3[ab]	52.0[ab]	5.3	11.4
4	53.7[cd]	34.0[b]	56.7[b]	10.0	21.4
5	46.7[bc]	32.7[ab]	55.3[b]	8.7	18.6
6	49.7[bcd]	34.0[b]	54.0[ab]	7.3	15.7
7	55.7[d]	34.3[b]	55.7[b]	9.0	19.3
CV%	14.5	13.4	9.9		
$LSD_{(0,05)}$	8.6	6.9	8.5		
Season 2 (1/11/2020 – 29/11/2020)					
1	34.3[a]	29.7[a]	47.7[a]		
2	39.3[ab]	31.3[ab]	49.3[ab]	1.7	3.5
3	45.3[bc]	33.0[ab]	51.0[ab]	3.3	7.0
4	49.0[c]	35.3[b]	54.7[b]	7.0	14.7
5	39.7[ab]	31.3[ab]	51.7[a]	4.0	8.3
6	47.3[c]	35.0[b]	52.0[ab]	4.3	9.1
7	50.0[c]	35.7[b]	56.0[b]	8.3	17.5
CV%	14.6	10.1	8.9		
$LSD_{(0,05)}$	6.6	5.2	6.9		

(CV: Coefficient of variation, LSD: Least Significant Difference. Different letters show statistical different at $P < 0.05$).

In clay soil, the developed fertilizer also improved its yield components and increased the yield of mustard greens compared to the control. Hence, from the increase of the above yield components, the yield of mustard greens in season 1 increased from 8.4 to 21.4% compared to the control, and in season 2, increased from 3.5 to 17.5% compared to the control. In the formulas that were supplemented with fertilizer, the plants grew quickly, and the leaves and stems were larger than the control. Thus, after deducting the expenses incurred due to the additional use of organic fertilizers, the net profit is from 17,000,000 - 42,000,000 VND/ha/crop.

4. CONCLUSIONS

The experimental results show that the two organic products produced have nutritional criteria and limiting factors that meet the requirements of QCVN 01-189:2019/BNNPTNT for organic fertilizers. Both fertilizers have a positive effect on the growth and development of plants, shown by increasing yields from 0.7 - 10 tons/ha/crop (1.4 - 21.4%) compared to with the control, net profit is from 500,000 - 42,000,000 VND/ha/crop. In particular, both types of organic fertilizers applied with a dosage of 3,000 kg/ha/crop have higher agronomic and economic efficiency. From the research results, it is possible to use the mentioned materials and apply the proposed mixing ratios to create organic fertilizer products to increase crop productivity.

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TÓM TẮT

ĐÁNH GIÁ HIỆU LỰC CỦA PHÂN HỮU CƠ MỚI PHÁT TRIỂN
BẰNG SỰ KẾT HỢP TỪ THAN TRẤU SINH HỌC, RONG BIỂN VÀ XÁC THỰC VẬT
TRÊN CÂY RAU CẢI XANH (*Brassica juncea*)

Lê Hữu Quang, Nguyễn Hải Âu
Viện Môi trường và Tài nguyên, ĐHQG TP.HCM
*Email: *lequang@wacc.edu.vn*

Bài báo này công bố kết quả nghiên cứu phối chế giữa than trấu sinh học, rong biển và xác bã thực vật ủ hoai mục theo các tỷ lệ khác để tạo ra 2 dòng phân bón hữu cơ mới cũng như đánh giá hiệu lực của chúng đến hiệu quả nông học và hiệu quả kinh tế trên cây cải xanh. Qua kết quả phân tích các chỉ tiêu chất lượng phân bón theo QCVN 01-189:2019/BNNPTNT thì 2 dòng phân bón trên đã đạt chất lượng của phân bón hữu cơ. Kết quả thử nghiệm hiệu lực nông học cũng như hiệu quả kinh tế của 2 dòng phân bón hữu cơ mới trên cây cải xanh cho thấy với liều lượng bón 3000 kg/ha/vụ làm tăng năng suất 10 tấn/ha (21,4%) so với đối chứng ở cả 2 vùng sinh thái riêng biệt và 2 loại đất khác nhau là đất xám và đất cát pha. Kết quả nghiên cứu này cho thấy có thể áp dụng 2 dòng phân bón hữu cơ trên vào canh tác canh nông nghiệp.

Từ khóa: Than sinh học, rong biển, phân hữu cơ, trấu, nguyên liệu hữu cơ.