Effect bulking agent on composting mexican sunflower (Tithonia diversifolia L) biomass and utilization on pak choi production

Jahra Pelu1,2,*, Setyono Y. Tyasmoro2, Moch. Dawam Maghfoer2
1Department of Plant Science, Faculty of Agriculture, University of Brawijaya, Malang, East Java, Indonesia.
2Department of Agrotechnology, Faculty of Agriculture, University of Brawijaya, Malang, East Java, Indonesia.
3Department of Agrotechnology, Faculty of Agriculture and Forestry, University of Iqra Buru, Namlea, Maluku, Indonesia.
Email: yayan2406uniqbu@gmail.com

ABSTRACT: Mexican sunflower or paitan in Indonesian (Tithonia diversifolia L) is a weed with high biomass production with nutrient quality that potentially use as composting material. However, there were problem for for optimize composting process due to low C/N ratio and high moisture content of this material. Therefore co-composting with higher C/N ratio and low moisture bulking materials to attain a proper composting process. Research to (1) Evaluate the effect of raw rice husk (RRH) and rice husk charcoal (RHC) as bulking agent on quality of compost T. diversifolia. Two composting mixture were TRRH = biomass T. Diversifolia + raw rice husk and TRHC = T. diversifolia biomass + rice husk biochar. Data were analyzed descriptively and compared with National Standards of Organic Fertilizer SNI 19-7030-2004. (2) To Compare the effect TRRH and TRHC compost on growth and yield of pak choi (Brassica rapa var chinensis). Plant height, number of leaves, leaf area, edible and total fresh weight and N uptake analyzed with ANOVA and mean difference with Tukey/HSD test. The results showed that (1) T. diversifolia L compost has nutritional quality of N, P, K in accordance with SNI 19-7030-2004, but the levels of N, P and K in TRHC > TRRH. (2) TTRH.40 planting media gave maximum growth and yield of pakchoy compared to other treatments. The study confirms that composting T. diversifolia L biomass were potential to enhance pak choi production while promoting cultivation of vegetables for food security.

Keywords: compost, pak choi, raw rice husk, rice husk biochar, Tithonia diversifolia L

INTRODUCTION

Food safety issues and environmental concerns about effect of the intensive use agrochemical in green revolusi era has contribute to development of organic farming over the last years. Compost almost use as a soil fertilizer or soil conditioner and to substitute commercial fertilizers in crop production. It has organic matter and nutrients content are valuable materials for increasing chemical, physical, biological properties of soil, stimulating root respiration and improve plant growth and yield (Cayuela et al., 2009; Guo et al., 2012). Compost is a product of breakdown biodegradable organic materials by microrganism into stabilized materials under controlled condition (de Bertoldi et al., 1983; Hubbe et al., 2010).

Mexican sunflower (Tithonia diversifolia L) or paitan in Indonesian is a weed plant that can survive in all soil conditions including critical soils with biomass production 2-4 ton.ha⁻¹.year⁻¹ and higher nutrient value compare to
animal manure. This biomass often used as a soil amandments and an alternative nutrient source (Munir & Swasono, 2012; Ojeniyi et al., 2012; Olabode et al., 2007; Pardono, 2011). This biomass potentially used as the main ingredient for composting. However, it has C/N ratio <15 where it were lower than those recomended for composting process (Bernai et al., 1998; Cayuela et al., 2009; Sahwan, 2004; Sweeten & Auvermann, 2008) caused fast mineralization nutrient especially in intial composting process that potential losses (Mahimairaja et al., 1994). Beside it, high moisture content of these biomass filled air pores and inhibit oxygen circulation or anaerobic condition. This condition can disrupt activity of microorganisms for decomposition process. Excessive moisture content of compost pile are leached also carry out dissolved nutrients that substantially reduces the nutrient value of the compost product (Adhikari et al., 2009; Maurya et al., 2018; Sundberg, 2005; Tiquia & Tam, 2000).

Previous study showed that co-composting high C/N and low moisture bulking material (bulking agent) with low C/N ratio and high moisture organic materials were an option strategy to provide optimizing condition for microbial activities on decomposition organic materials (Bernal et al., 2009; Nugroho et al., 2010). Bulking materials modify and prevent physical compaction of substrates, balance C/N ratio of compost pile, increasing aeration rate and improving biological activity conditions and regulation of moisture (Adhikari et al., 2009; Epstein, 2011; Rosiana et al., 2013; Zaman & Sutrisno, 2007).

Low moisture content of bulking agent can absorb leachate during decomposition and keep the moisture in the pile to sustain the composting process (Adhikari et al., 2009; Iqbal et al., 2012), reduce nutrient losses and thus improving nutrient content of final Products (Gabhane et al., 2012). However, difference of C/N ratio, carbon structure, physical shape, particle size of bulking agent affected water absorption capacity, rate of decomposition, nutrition conserve and quality of final compost (Barrington et al., 2003; Bustamante et al., 2008; Chang & Chen, 2010; Supadma & Arthagama, 2008).

Charred organic material (biochar) that been proposed as novel bulking agent in composting process (Jindo et al., 2012; Yoshizawa et al., 2006, 2005). Biochar has a recalcitrant rich carbon increasing the surface and nanoporosity of the compost matrix and aeration properties (Glaser et al., 2002; Lehmann et al., 2012; Lehmann & Joseph, 2009) to enhance community structure and proliferation of microorganism (Jindo et al., 2012; Pietikäinen et al., 2000; Yoshizawa et al., 2006, 2005) thus the decomposition process takes faster.

Aromatic carbon structures of char absorb inorganic elements, volatile gases, nutrients dissolved (Hua et al., 2009; Steiner et al., 2010) prevent nutrients losses through leaching.
and gas volatil and produce a high quality com-
posts (Hua et al., 2009; Steiner et al., 2010).

There were about 20-30% rice husk as
waste from rice mill. It has been used as soil
amendment or additive/bulking agent in com-
posting (Adhikari et al., 2009; dela Cruz et al.,
2006; Dewi et al., 2013; Zaman & Sutrisno,
2007). Convert rice husk by biochar technology
to produce a char materials with higher carbon
and more pore than raw rice husk (Theeba et
al., 2012) that will optimizing composting pro-
cess and quality of compost. However, inform-
ation about effect of raw rice husk (RRH) and
rice husk char (RHC) on composting T. diversi-
folia L biomass and compare it’s potential as soil
amendment and fertilizer were scarce. There-
fore, we are take more attention about it in this
work.

Pak choi (Brassica rapa var chinensis) is a
leafy vegetable with high nutrient content, an-
tioxidant, anticarcinogenic, antiviral properties
to maintain human health. The content of vit-
amins A, C, folic acid, beta-carotene and calci-
um in pak choi is higher than other types of
cabbage (Opena & Tay, 1994; Tshikalange,
2006). Pak choi often widely planted in a pot /
container system because it has a shallow root
structure (Boonsiri et al., 2009).

Previous study showed that effect com-
post as component of growing medium to in-
crease pak choi production depend on variation
source of compost materials, nutrient content,
dosage or composition on growing medium,
and the other aspect as plant growth promoter
or toxicity of compost.

The objective of this study were to 1) eval-
uate the the composting process of T. di-
versifolia L biomass with the addition raw rice
husk (RRH) and rice husk biochar (RHC) as bul-
kling agent and 2) compare the effect of persen-
tase T. diversifolia L compost as component
growing on the growth and production of pak
choi plants.

The result of this study hopefully will
provide practical information to use T. diversi-
folia L biomass compost with different bulking
agent as a novel soil amandments and fertilizer
on organic agriculture system.

**MATERIALS AND METHODS**

Research to evaluate quality of compost
T. diversifolia L biomass with bulking agent
RRH) and RHC was conducted at Organic fertil-
er production house of Brenjonk Organic
Farmer, Penanggungan Village, Trawas District,
Mojokerto, East Java whereas analysis of com-
post quality was conducted at the Soil Chemis-
try Laboratory, Department of Soil Science,
Faculty of Agriculture, University of Brawijaya
Malang during October 2012 to January 2013
(12 weeks).

Materials for composting were Tithonia
diversifolia biomass, raw rice husk, rice husk
biochar (Table 1), decomposer solution (water
+ EM 4+ molasses). Air-dried T. diversifolia L
biomass (stem and leaves) were cutting manu-
ally into small pieces 3 –5 cm and then mixing homogeneously with bulking agents to desire ratios treatments such as treatments. The mixture of treatments was prepared based on fresh weight (FW) such as TRRH = 80 % T. diversifolia L biomass + 20% raw rice husk and TRHC = 80% T. diversifolia L biomass + 20% rice husk biochar (w/w).

Tabel 1. Characteristic of organic materials

| Characteristic       | Organic materials       |
|----------------------|-------------------------|
|                      | T. diversifolia L)      |
|                      | Raw rice husk (RRH)     |
|                      | Rice husk biochar (RHC) |
| Total-N (%)          | 4.23 ±0.09              |
|                      | 1.38±0.06               |
|                      | 0.85 ±0.03              |
| Total-P (%)          | 2.07 ±0.09              |
|                      | 1.04 ±0.11              |
|                      | 0.63 ±0.06              |
| Total-K(%)           | 4.08 ±0.16              |
|                      | 2.37 ± 0.10             |
|                      | 1.87 ±0.11              |
| Total-C.org (%)      | 31.73 ±1.00             |
|                      | 40.28 ±0.76             |
|                      | 61.40 ±0.69             |
| C/N                  | 7.51 ±0.16              |
|                      | 29.23 ±1.64             |
|                      | 72.27 ±1.49             |
| Moisture content (%) | 49.30±1.18              |
|                      | 15.48 ±0.96             |
|                      | 7.10 ±1.26              |

Compost processed in open windrow composting system with pile dimension were 1.5 m x 1.0 m x 0.5 m. Compost piles were manually turned once time a week.

The effects of these bulking agents on the composting process were evaluated based on the changes in temperature as indicator of compost maturity progress (Adhikari et al., 2009), monitored at : 0, 3, 7, 14,21, 28, 35,42, 49,56 and 63 days.

Quality of compost include total nitrogen (TN), total phosphor (TP), total potassium (TK), total carbon (TC), C/N ratio at intial and final composting process. Samples taked randomly from four spot, dried and grounded to pass through 2 mm sieve for analysis. Data quality of compost were interpreted by compare mean of nutrient value with the Indonesian National standard of organic fertilizer (SNI 19-7030-2004).

Study to compare the effect of TRRH compost and TRHC compost as component of growing media on pak choi production conducted in the greenhouse of Brenjonk Organic Farm, Penanggungan Village, Trawas, Mojokerto, East Java during February to April 2013 use a Completely Randomized Design (CRD) with three replication and six treatments. Treatments consists of percentage T. diversifolia compost as soil mixing media such as : TRRH10 = 10% TRRH (v/v), TRRH 20 =20% TRRH (v/v), TRRH 40 = 40% TRRH (v/v), TRHC 10 = 10% TRHC (v/v), TRHC 20 = 20% TRHC (v/v), TRHC 40 = 40% TRHC (v/v).

Data recorded were plant height (cm), measured from the base of the plant to the tip of the longest leaf and number of leaves (sheet) are counted at 14,24, 34 and 44 days after planting (DAP). Leaf area (cm²) measured with portable leaf area meter (Model- Licor - 300C, Lincon), edible part (fresh leaf and stem) and total fresh (leaf + stem + root) weight measured using an electronic balance, N-uptake de-
Determined by the micro-Kjeldahl method (AOAC, 1984) after harvest.

Data were analyzed by analysis of variance (Anova) for a completely randomized factorial design model followed by Tukey/Honestly Significant Difference (HSD) test (P<0.05) to compare means. Pearson’s correlations were using to relationship between N-uptake and growth and yield parameter with software SPSS statistical package (SPSS for windows, USA).

RESULTS AND DISCUSSIONS
Effect bulking agent on composting process and quality of compost T. Diversifolia L. biomass

Decomposition complex organic material substrate to a simple component by microorganism generated heat. Normally, the compost temperature went through under three phases during decomposition process such as mesophilic, thermophilic and curing/maturity phase. Mesophylic is the temperature adjustment and maximizing the diversity of microbes to decomposition organic material. These temperature around 35-40°C and then temperature continues rise along with composting time to achieved peak temperature of thermophilic phase or active phase at 45-70°C. Afterwards temperature decreased gradually until reach ambient temperature or curing/maturity phase. The change of temperature correlate with microbial activities during composting process (Kumar et al., 2010; Wahyono et al., 2008). Therefore, dynamic temperature of compost pile were used as parameter to monitor the performance composting process in this study.

Gambar 1. The temperature dynamics on composting processes of T. diversifolia L biomass with bulking agent raw rice husk (RRH) and rice husk biochar (RHC).
Dynamic of temperature (Figure 1) showed that there were different trend of
temperature dynamic although the initial C/N ratio of TRRH and TRHC compost piles were ap-
propriate recommended range for optimum
decomposition (Bernal et al., 2009). TRHC com-
post pile (C/N = 20.25), mesophilic phase start at 3 days, thermophilic phase reached 43.75 °C
(21 days), 49.00 °C (28 days) and 49.25 °C (35 days), curing/maturity phase of 45.25 °C (42
days). While at TRHC (C/N= 29.75), mesophilic phase start at 3 days, thermophilic phase reached 42.75°C (7 days), 53.5°C (14 days),
52.55°C 21 days), 52.55°C (28 days), and reached curing/maturity phase of 43.25°C (35
days). It indicated that TRHC has shorter time to reach the thermopylic/active phase with
longer time, higher peak temperature and faster time for lasted composting than TRRH com-
post. Difference microbial activity due to differ-
ent initial C/N ratio initial compost mixture
(Theeba et al., 2012; Zhu, 2007). Use RHC as
bulking agent on T. diversifolia L provide balance carbon an nitrogen to support growth of
microorganisms and promoted abundance mi-
crobial communities. Therefore, THRC has high
microbial activity than TRRH. Contrasted with
previous works by (Zhu, 2007) that composted
swine manure bulking agent saw dust at C/N ratio 25 has the thermophilic phase (>50 °C) at
306 hour while C/N ratio 20 at 286 hour.

Difference of dynamic temperature of TRRH and TRHC compost pile possibly affected
by difference carbon structure of bulking agent.
Song et al. (2008) on Theeba et al. (2012) re-
ported that heating/pyrolysis process caused
different carbon structure of RRH and RHC.
RHH has a relatively smooth surface with a
globular structure on the outside and rough
space with slit-like cells on the other side while RHC has various opened pores on the rough
surface. Yoshizawa et al. (2005) and et al. Yo-
shizawa (2006) found that aerobic microorgan-
isms proliferated on the surface of the charcoal
and in the vicinity of the pore openings. In line
with Jindo et al. (2012) also reported that bio-
char has range of pores properties. Macro pore
has selective sorption of organic compounds,
while micropore of biochar captured excess
moisture content and soluble nutrient to re-
duce anaerobic sacs in compost piles. These
mecahnisms provides aerobic condition and
nutrient for proliferation of aerobic microbial
(Dias et al., 2010; Tanaka et al., 2006).

Therefore, it expected that presence RHB
on THRC compost pile caused the large micro-
bial population and diversity to enhance activi-
ty of decomposition process caused generate
the temperature to thermophilic range with
prolonged peak temperature on active phase
and shorter time to reached curring phase
compared to TRRH. This findings similar with
reported by Theeba et al. (2012) and Dias et al.
(2010) that different carbon structure of bul-
kling agent also affected heat generated of com-
posting pile.
Nutrient turnover in composting mixture due to the microbial activity. Total nitrogen (TN) decreased by 58.28% (TRRH) and 31.04% (TRHC) respectively or nitrogen losses on TRHC < TRRH (Figure). Adhikari et al. (2009), Kumar et al. (2010) and Sundberg (2005) found that nitrogen losses on composting process through gasses volatilization NH$_3$, N$_2$O, N$_2$, or NOx compounds and leaching dissolved nitrogen such as NH$_4^+$ and NO$_3^-$. Difference of nitrogen losses of two compost mixture indicated capabilities bulking agent of RRH and RHC to conserve nitrogen and avoid it losses on T. diversifolia L compost pile due to different C/N ratio. De Bertoldi et al. (1983) and Tiquia et al. (2002) stated that the high C/N ratio of initial compost mixture affected immobilization nitrogen or low concentration of mineralization nitrogen on the compost pile. Therefore, different C/N ratio of RHC > RRH (Table 1) affected higher C/N ratio of intial compost mixture of TRHC than TRRH (Figure 2d), therefore TRHC has a low nitrogen mineralisation in initial composting process and potential loss were low too.

Different cation exchange capacity also affected capability bulking agent ti reduce nitrogen losses on composting process. RRH Masulili et al. (2010) found that rice husk biochar (RHC) has a high cation exchange capacity than raw rice husk caused it has high ability to adsorption N-ammonium (NH$_4^+$-N) and reduce it leached. Adsorption NH$_4^+$-N affected in avoid possibly transformation to NH$_3$ and NO$_3^-$. Biochar of TRHC could retain moisture to reduce anaerobic sacs in compost piles that theoretically can inhibit the transformation of ammonia (NH$_3$-N) (Jindo et al., 2012). Biochar reduced the abundance of NO$_2$–N producing bacteria, and increase the abundance of N$_2$O-consuming bacteria affected on low concentration of NO$_2$-N (Clough et al., 2013). These mechanisms will prevent nitrogen losses through ammonia volatilization and ammonium or nitrate leaching. Therefore, it probably caused RHC has better ability to reduce nitrogen losses than RRH. Therefore, TRHC compost has highest nitrogen content than TRRH compost.

Losses of P and through run-off and leaching (Tiquia et al., 2002). Total phosphor (TP) decreased by 18.97% (TRRH) and 9.64% (TRHC) respectively (Figure ). Phosphor losses in TRHC < TRRRH compost because high carbon content of RHC than RRH affected C/P ratio of composting mixture and mineralization rate of phosphor organic on beginning composting process (Dias et al., 2010). Therefore, if the concentration is low, the potential for losses by leaching were low too. Biochar has internal porosity, high surface area and surfaces sites promote absorption of nutrient and have high cation exchange capacity to retain cation include HPO$_4^{2-}$ (Laird et al., 2010; Novak et al., 2009). Therefore, it is assumed that this mech-
anism also caused low losses of P on TRHC compost than TRRH compost.

Potassium (K) losses through leaching mineralized potassium (Rosolem & Calonego, 2013). In this study, total potassium (TK) decreased by 32.20% (TRRH) and 20.22% (TRHC) respectively (Figure) or K losses on TRHC < TRRH because biochar on TRRH has high cation exchange capacity could bind cations such K⁺ or soluble potassium on compost pile and reduce it leached.

The use of carbonized materials as a bulking agent in composting process increases diversity, and their activity to increase nutrients values of compost (Dias et al., 2010; Jindo et al., 2012; Steiner et al., 2010; Theeba et al., 2012; Yoshizawa et al., 2005).

Gambar 2. (a) Total Nitrogen (TN), Total Phosphor (TP) and total (TK); b) Total Organic Carbon (TOC); c) C/N ratio on composting T. diversifolia L with bulking agent raw rice husk (TRRH) and rice husk biochar (TRHC).

During decomposition occurs, microbial utilize carbon as a source of energy and then break down carbon. Temitted CO₂ and CH₄ from composting pile as a metabolic product. It affected declined total organics carbon (TOC) of composting mixture. TOC decreased by 69.69% (TRRH) and 57.12% (TRHC) respectively (Figure 2b) or total carbon losses in TRHC < TRRH. This may be attributed to different carbon structure of bulking agent. RRH has RHC has recalcitrant carbon materials that caused partially decomposition carbon of biochar during the composting process. Therefore, high of C content of
TRHC because presence undecomposed biochar.

C/N ratio decreased by 41.93% (TRRH) and 30.57% (TRHC) respectively (Figure 2c) due to decrease TN and TC content (figure 2a and 2b). The final C/N ratio of both composites was less than 20, which indicates the achievement of a stable and mature compost (Huang et al., 2004).

Losses of nutrient reduce the agronomic value of the end-product where N, P, K, C and C/N ratio values of TRRH were 1.72 ± 0.04; 1.12 ± 0.09; 2.58 ± 0.07 when compared with TRHB 2.31 ± 0.02; 1.08 ± 0.05; 2.88 ± 0.03. Hence NPK content of the final compost in present study are has a higher nutritional value than the minimum standard of Indonesian National Standard (SNI) of N,P,K, C and C/N ratio were 0.4 – 3.5% of nitrogen, 0.3-3.5% phosphorus and 0.5 -1.8% potassium.

Effect *Tithonia diversifolia* L compost on growth, yield and nitrogen uptake of pak choi

Anova test showed that significant effect of *T. diversifolia* L compost treatments on plant height for 24, 34 and 44 DAI, leaf number for 44 DAT, leaf area, edible fresh weight, total fresh weight, N-uptake of pak choi.

Tukey’s HSD test showed that maximum plant height of pak choi at 24 DAT were TRHC<sub>40</sub> and TRHC<sub>20</sub> treatment; at 34 DAT were TRHC<sub>40</sub>, TRHC<sub>20</sub> and CT-B<sub>40</sub> treatment; at 44 DAT were TRHC<sub>40</sub> and TRHC<sub>20</sub>. Whereas the minimum plant height of pak choi at 24 DAT were TRRH<sub>10</sub>; 34 DAT were TRRH<sub>10</sub>; 44 DAT were TRRH<sub>10</sub> and TRHC<sub>10</sub> DAT (Figure 3a). Maximum number of leaves of pak choi at 44 DAT were TRHC<sub>40</sub> and TRRH<sub>40</sub> treatments whereas the minimum were TRRH<sub>10</sub>, and TRHC<sub>10</sub> (Figure 3b). Maximum leaf area were TRHC<sub>40</sub> whereas the minimum were TRRH<sub>10</sub> and TRHC<sub>10</sub> treatments (Figure 3c). Maximum edible fresh weight were TRHC<sub>40</sub> whereas the minimum were TRRH<sub>10</sub> treatments. Maximum total fresh weight were TRHC<sub>40</sub> whereas the minimum were TRRH<sub>10</sub> (Figure 3d). Maximum nitrogen uptake were TRHC<sub>40</sub> whereas the minimum were TRRH<sub>10</sub> and TRHC<sub>10</sub> (Figure 3e).
Figure 3. Effect *T. diversifolia* L + raw rice husk (TRRH) and *T. diversifolia* L + rice husk biochar (TRHC) compost on plant height (a), number of leaves (b), edible fresh weight and total fresh weight (c), leaf area (d) and N-uptake (e) of pak choi. Vertical bar were standard deviation (n=3). Different letters indicate significant difference at HSD test (P<0.05).

Significant different of N-uptake of the treatments (Figure 3e) probably affected by available nitrogen concentration on growing media that linked with difference of rate of nitrogen mineralization of type of compost and their dose on soil mixture. Total nitrogen content of TRHC compost > TRRH compost (Gambbar) has direct contribution to available nitrogen on growing medium. Beside it, these effect maybe associated with sinergytic effect biochar and compost of TRHC compost on soil nitrogen dynamic and transformation dan plant uptake (Clough & Condron, 2010; Glaser et al., 2002; Lehmann et al., 2012). Therefore, it possibly affected on highest N uptake of pak choi on TRHC40.

Biochar increase soil chemical properties such as cation exchange capacity, (Biederman & Harpole, 2013; Gusmailina, 2010; Masulili et al., 2010; Prendergast-Miller et al., 2014; Spokas & Reicosky, 2009) affected absorption of cations N-NH₄⁺ and reduce leaching soluble nitrogen (N-NH₄⁺ and N-NO₃⁻) or gaseous losses (NH₃, N₂ or N₂O). Biochar- compost tends to release its nutrients more slowly providing, decreasing nutri-
ent leaching and therefore persistent in soil to plant uptake (Gusmailina, 2010). Thus with these mechanisms would increase the total pool of available nitrogen to pak Choi uptake.

Correlation between N-uptake and the growth and yield of pak Choi were very strong \((R>0.80)\) and \(R^2\) value or contribution N-uptake to plant height, number of leaves, leaf area, edible fresh weight and total fresh weight were 87.93%, 67.56%, 72.86%, 70.56% and 71.04% (Figure 4). It indicated that N-uptake has more contributed to increased growth and yield parameters of pak Choi.

Nitrogen has been shown plays an important role in plant growth and yields, which as a constituent of chlorophyll that regulate process of photosynthesis. Nitrogen also acts as a growth regulator such as cytokinins that support cell division and auxin that support the lengthening of cells. The Photosynthates such as polysaccharides, lipids, proteins and amino acids were distributed to cell division in apical shoot meristems and in primordial leaf cells causes an increase in the number of cells. Therefore, the highest N-uptake on TRHC40 increase the amount of chlorophyll formed and the rate of photosynthesis of pakcoy plants. Thus, through the increase in photosynthetic activity of leaves, it further encourages vegetative growth of pak Choi such as plant height (Figure 4a ), number of leaves (Figure 4b), leaf area (Figure 4c), edible fresh weight (Figure 3d) and total fresh weight (Figure 4e).

Figure 4. Relationship between N-uptake (X) with (a) plant height, (b) number of leaves, edible fresh weight (c), total fresh weight (d), leaf area (e) of pak Choi.

DOI: https://doi.org/10.35891/agx.v11i1.1906
Another possibility for highest growth and yield of pak choi in TRHC\textsubscript{40} treatment could be assumed that positive synergistic effects of high nutrient content of \textit{T. diversifolia} \textit{L} and recalsitrant carbon of rice husk biochar on compost to improve physical structure, chemical properties and biological processes on soil (Gusmailina, 2010; Lehmann & Rondon, 2006) and boosts plant growth (Schulz et al., 2013). Release of nutrients from TRHC\textsubscript{40} provide enough nutrients for pak choi and supported by the presence of biochar in THRC which has range of pore sizes. Micropores serve as capillary spaces with high surface area to volume ratios and can retain water and nutrient, while macropores of biochar can serve as gas exchange channels which can directly influence root respiration (Schmidt et al., 2014).

Asai et al. (2009) and Yu et al. (2013) stated that biochar has potential to increase water holding capacity and increase crop yields in loamy sand soil. Schulz et al. (2013) Prost et al. (2013) found that increased water holding capacity also help retained dissolved nutrient prevent nutrient losses, increase water available for plants and decreased drought stress of plants (Liu et al., 2012; Sohi et al., 2010). The porous structure of biochar were a suitable habitat for microbial proliferation (Tanaka et al., 2006) therefore increase the microbial population and their activity in soils could improve bioavailability of nutrient to the plant and stimulate the release of plant growth promoting hormones which can subsequently affect soil fertility (Schmidt et al., 2014). Similar results were observed Komarayati & Pari (2012), Nur et al. (2014), Schmidt et al., (2014), and Kammann et al. (2014) who reported that addition of positive effect compost-biochar on increase soil fertility and plant production.

Results of the present study give a positive indication that utilization rice husk biochar to optimize composting process of \textit{T. diversifolia} \textit{L} biomass and produced a nutrient-rich compost with beneficial effects for growing medium.

**CONCLUSION**

Based on the results of the study it can be conclude that biochar rice husk (RHC) effectively accelerates the composting process and improves the nutrient quality of \textit{T. diversifolia} than raw rice husk (RRH). Application of TRHC compost at a dose of 40\% (v/v) (TRHC\textsubscript{40}) increases nitrogen uptake, plant height, number of leaves, leaf area, edible and total fresh weight of pak choi.

**ACKNOWLEDGEMENTS**

We are very grateful for the financial support by the Yayasan Muslim Buru. We would like to express our deep gratitude to Mrs. Mintarti and Mr. Slamet (Brenjonk Organic Farm) for facilitate on composting process and greenhouse research. To Mrs. Padmi Wulandari thankfull for help on analysis in Laboratorium.
of Soil Chemical, Faculty of Agriculture, University of Brawijaya.

REFERENCES

Adhikari, B. K., Barrington, S., Martinez, J., & King, S. (2009). Effectiveness of three bulking agents for food waste composting. Waste Management, 29(1), 197–203. https://doi.org/10.1016/j.wasman.2008.04.001

Asai, H., Samson, B. K., Stephan, H. M., Songyikhangsuthor, K., Homma, K., Kyono, Y., Inoue, Y., Shiraiwa, T., & Horie, T. (2009). Biochar amendment techniques for upland rice production in Northern Laos: 1. Soil physical properties, leaf SPAD and grain yield. Field Crops Research, 111(1), 81–84. https://doi.org/10.1016/j.fcr.2008.10.008

Barrington, S., Choinière, D., Trigui, M., & Knight, W. (2003). Compost convective airflow under passive aeration. Bioresource Technology, 86(3), 259–266. https://doi.org/10.1016/S0960-8524(02)00155-4

Bernal, M. P., Paredes, C., Sánchez-Monedero, M. A., & Cegarra, J. (1998). Maturity and stability parameters of composts prepared with a wide range of organic wastes. Bioresource Technology, 63(1), 91–99. https://doi.org/10.1016/S0960-8524(97)00084-9

Bernal, M. P., Alburquerque, J. A., & Moral, R. (2009). Composting of animal manures and chemical criteria for compost maturity assessment. A review. Bioresource Technology, 100(22), 5444–5453. https://doi.org/10.1016/j.biortech.2008.11.027

Biederman, L. A., & Harpole, W. S. (2013). Biochar and its effects on plant productivity and nutrient cycling: A meta-analysis. GCB Bioenergy, 5(2), 202–214. https://doi.org/10.1111/gcbb.12037

Boonsiri, K., Suangsang, D., Pirommi, S., Seang, A., Tongying, W., Kontha, J., & Weejitian, A. (2009). Effect of granular organic fertilizers on growth and yield of pak choi and Rice cv. Phitsanulok 60-2. Asian J. Food Agro-Industry (Special Issue): S160-S163, Special, 160–163.

Bustamante, M. A., Paredes, C., Marhuenda-Egea, F. C., Pérez-Espinosa, A., Bernal, M. P., & Moral, R. (2008). Co-composting of distillery wastes with animal manures: Carbon and nitrogen transformations in the evaluation of compost stability. Chemosphere, 72(4), 551–557. https://doi.org/10.1016/j.chemosphere.2008.03.030

Cayuela, M. L., Mondini, C., Insam, H., Sinicco, T., & Franke-Whittle, I. (2009). Plant and animal wastes composting: Effects of the N source on process performance. Bioresource Technology, 100(12), 3097–3106. https://doi.org/10.1016/j.biortech.2009.01.027

Chang, J. I., & Chen, Y. J. (2010). Effects of bulking agents on food waste composting. Bioresource Technology, 101(15), 5917–5924. https://doi.org/10.1016/j.biortech.2010.02.042

Clough, T. J., & Condron, L. M. (2010). Biochar and the Nitrogen Cycle: Introduction. Journal of Environmental Quality, 39(4), 1218–1223. https://doi.org/10.2134/jeq2010.0204

Clough, T. J., Condron, L. M., Kammann, C., & Müller, C. (2013). A review of biochar and soil nitrogen dynamics. Agronomy, 3(2), 275–293. https://doi.org/10.3390/agronomy3020275

de Bertoldi, M., Vallini, G., & Pera, A. (1983). The biology of composting: A review. Waste Management & Research, 1(2), 157–176. https://doi.org/10.1016/0734-242X(83)90055-1

dela Cruz, N. E., Aganon, C. P., Patricio, M. G., Romero, E. S., Lindain, S. A., & Galindez,
J. L. (2006). Production of organic fertilizer from solid waste and its utilization in intensive organic-based vegetable production and for sustaining soil health and productivity. *International Workshop on Sustained Management of the Soil-Rhizosphere System for Efficient Crop Production and Fertilizer Use*, 16, 20.

Dewi, A. B., Pujiastuti, N., & Fajar, I. (2013). *Ilmu gizi untuk praktisi kesehatan*. Graha Ilmu.

Dias, B. O., Silva, C. A., Higashikawa, F. S., Roig, A., & Sánchez-Monedero, M. A. (2010). Use of biochar as bulking agent for the composting of poultry manure: Effect on organic matter degradation and humification. *Bioresource Technology, 101*(4), 1239–1246. https://doi.org/10.1016/j.biortech.2009.09.024

Epstein, E. (2011). *Industrial Composting: Environmental Engineering and Facilities Management*. CRC Press.

Guo, R., Li, G., Jiang, T., Schuchardt, F., Chen, T., Zhao, Y., & Shen, Y. (2012). Effect of aeration rate, C/N ratio and moisture content on the stability and maturity of compost. *Bioresource Technology, 112*, 171–178. https://doi.org/10.1016/j.biortech.2012.02.099

Gusmailina, G. (2010). Pengaruh arang kompos bioaktif terhadap pertumbuhan anakan bulian (Eusyderoxylon zwageri) dan gaharu (Aquilaria malaccensis). *Jurnal Penelitian Hasil Hutan, 28*(2), 93–110.

Hua, L., Wu, W., Liu, Y., McBride, M. B., & Chen, Y. (2009). Reduction of nitrogen loss and Cu and Zn mobility during sludge composting with bamboo charcoal amendment. *Environmental Science and Pollution Research, 16*(1), 1–9. https://doi.org/10.1007/s11356-008-0041-0

Hubbe, M. A., Nazhad, M., & Sánchez, C. (2010). Composting as a way to convert cellulotic biomass and organic waste into high-value soil amendments: A review. *BioResources, 5*(4), 2808–2854.

Iqbal, M. K., Nadeem, A., Khan, R. A., & Hussnain, A. (2012). Comparative study of different techniques of composting and their stability evaluation in municipal solid waste. *Journal of The Chemical Society of Pakistan, 34*(6), 273–282.

Jindo, K., Suto, K., Matsumoto, K., García, C., Sonoki, T., & Sanchez-Monedero, M. A. (2012). Chemical and biochemical characterisation of biochar-blended composts prepared from poultry manure. *Bioresource Technology, 110*, 396–404. https://doi.org/10.1016/j.biortech.2012.01.120

Kammann, C., Haider, G., Messerschmidt, N., Schmidt, H.-P., Koyro, H.-W., Steffens, D., Clough, T., & Müller, C. (2014). Co-composted biochar can promote plant growth by serving as a nutrient carrier: First mechanistic insights. *16*(1), 15635.

Kumar, M., Ou, Y.-L., & Lin, J.-G. (2010). Co-composting of green waste and food waste at low C/N ratio. *Waste Management, 30*(4), 602–609. https://doi.org/10.1016/j.wasman.2009.11.023
Laird, D. A., Fleming, P., Davis, D. D., Horton, R., Wang, B., & Karlen, D. L. (2010). Impact of biochar amendments on the quality of a typical Midwestern agricultural soil. *Geoderma, 158*(3), 443–449. https://doi.org/10.1016/j.geoderma.2010.05.013

Lehmann, J., & Joseph, S. (2009). *Biochar for environmental management* (1st ed.). Routledge. https://doi.org/10.4324/9781849770552

Lehmann, J., Joseph, S., & Joseph, S. (2012). *Biochar for environmental management: Science and technology*. Routledge. https://doi.org/10.4324/9781849770552

Lehmann, J., & Rondon, M. (2006). Bio-char soil management on highly weathered soils in the humid tropics. *Biological Approaches to Sustainable Soil Systems, 113*(517), e530.

Liu, J., Schulz, H., Brandl, S., Miehtke, H., Huwe, B., & Glaser, B. (2012). Short-term effect of biochar and compost on soil fertility and water status of a Dystric Cambisol in NE Germany under field conditions. *Journal of Plant Nutrition and Soil Science, 175*(5), 698–707. https://doi.org/10.1002/jpln.201100172

Mahimairaja, S., Bolan, N. S., Hedley, M. J., & Macgregor, A. N. (1994). Losses and transformation of nitrogen during composting of poultry manure with different amendments: An incubation experiment. *Bioresource Technology, 47*(3), 265–273. https://doi.org/10.1016/0960-8524(94)90190-2

Masulili, A., Utomo, W. H., & Syechfani, M. S. (2010). Rice husk biochar for rice based cropping system in acid soil 1. The characteristics of rice husk biochar and its influence on the properties of acid sulfate soils and rice growth in West Kalimantan, Indonesia. *Journal of Agricultural Science, 2*(1), 39.

Maurya, V. K., Gothandam, K. M., Ranjan, V., Shakya, A., & Pareek, S. (2018). Effect of drying methods (microwave vacuum, freeze, hot air and sun drying) on physical, chemical and nutritional attributes of five pepper (Capsicum annuum var. Annuum) cultivars. *Journal of the Science of Food and Agriculture, 98*(9), 3492–3500.

Munir, M., & Swasono, M. A. H. (2012). Potensi pupuk hijau organik (daun trembesi, daun paitan, daun lantoro) sebagai unsur kestabilan kesuburan tanah. *Agromix, 3*(2), 1–17. https://doi.org/10.35891/agx.v3i2.750

Novak, J. M., Busscher, W. J., Laird, D. L., Ahmedna, M., Watts, D. W., & Niandou, M. A. S. (2009). Impact of Biochar Amendment on Fertility of a Southeastern Coastal Plain Soil. *Soil Science, 174*(2), 105–112. https://doi.org/10.1097/SS.0b013e3181981d9a

Nugroho, J., Bintoro, N. S., & Nurkayanti, T. (2010). Pengaruh variasi jumlah dan jenis bulking agent pada pengomposan limbah organik sayuran dengan komposter mini. *Seminar Nasional Perhimpunan Ahli Teknik Pertanian 2010, 606–611.* https://repository.ugm.ac.id/33088/

Nur, M. S. M., Islami, T., Handayanto, E., Nugroho, W. H., & Utomo, W. H. (2014). The use of biochar fortified compost on calcareous soil of East Nusa Tenggara, Indonesia: 2. Effect on the yield of maize (Zea Mays l) and phosphate absorption. *American-Eurasian Journal of Sustainable Agriculture, 105–112.*

Ojeniyi, S. O., Odedina, S. A., & Agbede, T. M. (2012). Soil productivity improving attributes of mexican sunflower (Tithonia diversifolia) and siam weed (Chromolaena odorata). *Emirates Journal of Food and Agriculture, 24*(3), 243–247.

Olabode, O. S., Sola, O., Akanbi, W. B., Adesina, G. O., & Babajide, P. A. (2007). Evaluation of Tithonia diversifolia (Hemsl.) A Gray for soil improvement. *World Journal of Agricultural Sciences, 3*(4), 503–507.
Opena, R. T., & Tay, D. C. S. (1994). Brassica rappa L. Group Caisim. Plant Resource of South-East Asia. Vegetable. Prosea Foundation. Hal, 153–157.

Pardono, -. (2011). Potensi Chromolaena odorata dan Tithonia diversifolia sebagai sumber nutrisi bagi tanaman berdasarkan kecepatan dekomposisinya (studi kasus di desa Sobokerto Boyolali Jawa Tengah). Agrovigor: Jurnal Agroekoteknologi, 4(2), 80–85. https://doi.org/10.35891/agrovigor.v4i2.296

Prendergast-Miller, M. T., Duvall, M., & Sohi, S. P. (2014). Biochar–root interactions are mediated by biochar nutrient content and impacts on soil nutrient availability. European Journal of Soil Science, 65(1), 173–185. https://doi.org/10.1111/ejss.12079

Pietikäinen, J., Kiikkilä, O., & Fritze, H. (2000). Charcoal as a habitat for microbes and its effect on the microbial community of the underlying humus. Oikos, 89(2), 231–242. https://doi.org/10.1034/j.1600-0706.2000.890203.x

Pietikäinen, J., Kiikkilä, O., & Fritze, H. (2000). Charcoal as a habitat for microbes and its effect on the microbial community of the underlying humus. Oikos, 89(2), 231–242. https://doi.org/10.1034/j.1600-0706.2000.890203.x

Pelly et al. / AGROMIX

Volume 11 No 1 (2020), Page: 49-65

DOI: https://doi.org/10.35891/agx.v11i1.1906

Scheid, H.-P., Kammann, C., Niggli, C., Evangelou, M. W. H., Mackie, K. A., & Abiven, S. (2014). Biochar and biochar-compost as soil amendments to a vineyard soil: Influences on plant growth, nutrient uptake, plant health and grape quality. Agriculture, Ecosystems & Environment, 191, 117–123. https://doi.org/10.1016/j.agee.2014.04.001

Schulz, H., Dunst, G., & Glaser, B. (2013). Positive effects of composted biochar on plant growth and soil fertility. Agronomy for Sustainable Development, 33(4), 817–827. https://doi.org/10.1007/s13593-013-0150-0

Sohi, S. P., Krull, E., Lopez-Capel, E., & Bol, R. (2010). Chapter 2—A Review of Biochar and Its Use and Function in Soil. In Advances in Agronomy (Vol. 105, pp. 47–82). Academic Press. https://doi.org/10.1016/S0065-2113(10)05002-9

Spokas, K. A., & Reicosky, D. C. (2009). Impacts of sixteen different biochars on soil greenhouse gas production. 3(612), 179–193.

Steiner, C., Das, K. C., Melear, N., & Lakly, D. (2010). Reducing nitrogen loss during poultry litter composting using biochar. Journal of Environmental Quality, 39(4), 1236–1242. https://doi.org/10.2134/jeq2009.0337

Sundberg, C. (2005). Improving compost process efficiency by controlling aeration, temperature and pH (Vol. 2005).

Supadma, A. A. N., & Arthagama, D. M. (2008). Uji formulasi kualitas pupuk kompos yang bersumber dari sampah organik dengan penambahan limbah ternak ayam, sapi, babi dan tanaman pahitan. Bumi Lestari Journal of Environment, 8(2), 113–121.

Sweeten, J. M., & Auvermann, B. W. (2008). Composting manure and sludge. Texas Agricultural Extension Service, L–2289, 1–7.
Tanaka, S., Yoshizawa, S., Ohata, M., Mineki, S., Goto, S., Fujioka, K., & Kokubun, T. (2006). Morphological change of microbial community structure during composting rice bran with charcoal. *Transactions-Materials Research Society of Japan, 31*(4), 981.

Theeba, M., Bachmann, R. T., Illani, Z. I., Zulkifli, M., Husni, M. H. A., & Samsuri, A. W. (2012). Characterization of local mill rice husk charcoal and its effect on compost properties. *Malaysian Journal of Soil Science, 16*(1), 89–102.

Tiquia, S. M., Richard, T. L., & Honeyman, M. S. (2002). Carbon, nutrient, and mass loss during composting. *Nutrient Cycling in Agroecosystems, 62*(1), 15–24. https://doi.org/10.1023/A:1015137922816

Tiquia, S. M., & Tam, N. F. Y. (2000). Fate of nitrogen during composting of chicken litter. *Environmental Pollution, 110*(3), 535–541. https://doi.org/10.1016/S0269-7491(99)00319-X

Tshikalange, T. E. (2006). *Response of Brassica rapa L. subsp. Chinensis to nitrogen, phosphorus and potassium in pots* [Thesis, Tshwane University of Technology]. http://tutvital.tut.ac.za:8080/vital/access/manager/Repository/tut:3898

Wahyono, S., Sahwan, F. L., Martono, J. H., & Suyanto, F. (2008). Evaluasi teknologi penanganan limbah padat industri sawit. *Prosiding Seminar Teknologi Untuk Negeri, BPPT.*

Yoshizawa, S., Tanaka, S., Ohata, M., Mineki, S., Goto, S., Fujioka, K., & Kokubun, T. (2006). Promotion effect of various charcoals on the proliferation of composting microorganisms. 炭素, 224, 261–265. https://doi.org/10.7209/tanso.2006.261

Yoshizawa, S., Tanaka, S., Ohata, M., Mineki, S., Goto, S., Fujioka, K., & Kokubun, T. (2005). Composting of food garbage and livestock waste containing biomass charcoal. *Proceedings of the International Conference and Natural Resources and Environmental Management, 8*, 2011.

Yu, O.-Y., Raichle, B., & Sink, S. (2013). Impact of biochar on the water holding capacity of loamy sand soil. *International Journal of Energy and Environmental Engineering, 4*(1), 44. https://doi.org/10.1186/2251-6832-4-44

Zaman, B., & Sutrisno, E. (2007). Studi pengaruh pencampuran sampah domestik, sekam padi, dan ampas tebu dengan metode mac donald terhadap kematangan kompos. *Jurnal PRESIPITASI, 2*(1), 1–7.

Zhu, N. (2007). Effect of low initial C/N ratio on aerobic composting of swine manure with rice straw. *Bioresource Technology, 98*(1), 9–13. https://doi.org/10.1016/j.biortech.2005.12.003