The Nutritional Value of Shrimp Waste and Its Response to Growth and N Uptake Efficiency by Corn

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Abstract. Today's agricultural development is expected to be able to optimize the utilization of agricultural waste resources to improve soil fertility and nutrient for plants, such as the utilization of shrimp waste. This research was conducted to test the level of improvement of the soil fertility and the efficiency of N uptake of corn by application of shrimp waste. The study was conducted using a randomized block design, consisting of five treatments divided as control and the addition of biochar, shrimp waste, urea, and biochar+shrimp waste. Analysis using orthogonal contrast with biochar and shrimp waste was classified as ameliorant, while urea, and biochar+S as fertilizer. The results showed that the application of biochar+S was able to increase soil pH (4.9 out of 4.3), N-total is 85%, OC is 66.2%, CEC is 1.5 times the initial CEC, plant height and number of leaves at 56 days respectively 225 cm and 13 sheets, and Nitrogen uptake efficiency around 24.8% with a dry shell yield of around 10.6 t ha⁻¹. Biochar and biochar+S both increased P-available (4.8 out of 3.4 mg kg⁻¹), whereas K-available increased in shrimp waste applications (88 of 46.1 mg kg⁻¹)

Keyword: Soil Fertility, Nitrogen Uptake, Shrimp Waste, Biochar
1. Introduction

Agricultural wastes are non-product outputs from the production and processing of agricultural products that contain materials that can be reused by humans [1, 2]. The potential of agricultural waste is large and contributes to a significant portion of the total waste to 80% [3, 4]. It is that around 998 million tons of agricultural waste are produced annually [2, 5], about 52 million tons of dry matter is used as a source of ruminant feed [6], manure production reaches 5.27 kg day\(^{-1}\) out of 1000 kg of live weight based on wet weight [7, 8].

In this day and age, inorganic fertilizers are used to meet the needs of nitrogen for plants even though it has very low N uptake efficiency (17-28%) [9]. The efficient use of nitrogen is a key factor in agricultural sustainability, and the use of organic fertilizers can become a new alternative to increase the availability of nitrogen, organic carbon, and the productivity of soil [10-13] as it can be used as a renewable resource to increase the fertility and nutrients for plants.

Shrimp waste is one of the highest organic waste productions in Indonesia that has a potential value to be used as organic fertilizer [13-15]. Up to 15% of the shrimp production is an agricultural waste as 40-50% of the shrimp weight produces waste in the form of skin and head [9, 16]. The ability of shrimp waste to increase plant growth and efficiency of N depends on the chemical properties and the nutrient content of N in it. Available nitrogen is very important for plants because plants absorb N available in the nature through the root system [17]. The lack of N availability causes crop productivity to decrease, eutrophication, excess nitrate in groundwater, and increased nitrous oxide emissions [18, 21].

Shrimp waste contains 41.9% protein, 17.0% chitin, 29.2% ash, and 4.5% fat from dry matter, as well as essential amino acid protein [22, 15], which has an active site that can absorb heavy metals in the soil through ion exchange mechanisms or chelating formation [23-25]. The content of organic carbon in shrimp waste contributes to functional groups such as carboxyl (COOH) and hydroxyl (OH-), which can provide a positive influence on the dynamics of nitrogen in the soil [26, 27]. Crustacean shells (shrimp), generally contain 30-50% of the mineral of the dry weight, which is dominated by CaCO\(_3\), and containing 8-10% Ca\((PO_4)_2\) of the total inorganic material that can contribute nutrients [28, 29].

In addition to shrimp waste, the use of biochar is also recommended as a soil amendment to improve soil fertility and the environment [30, 31]. The biochar can increase organic matter and stable soil organic carbon reserves [30, 32], reduce CO\(_2\) and N\(_2\)O emissions [33] and increase retention of the Ammonium and Nitrate [34, 35], as a mechanism to reduce nitrogen losses because of N\(_2\)O emissions [36] or NH\(_3\) evaporation [37]. The presence of biochar in the soil plays an important role in increasing nutrients retention and reducing leaching [38-40]. Findings Agegnehu [41] show that the application of a compost biochar mixture significantly reduces the loss of the nitrogen, P, K, Ca and Mg [42].

Some of the results of shrimp waste research are more on the utilization of shrimp waste as a source of chitin and chitosan for the development of natural polymers the slow-release fertilizers. Chitosan produced from shrimp waste is very good as a fertilizer coating in the formulation of slow-release fertilizers [43]. Currently, many natural chitosan polymers are used as a controlling of rate nitrogen release from inorganic fertilizers [15], because chitosan has reactive functional groups such as amino, carboxyl, and hydroxyl, and high surface area that can retain and controlling nitrogen properly [24,25, 44, 45]. Chitin compounds obtained from shrimp waste contained 2.95% water, ash content 0.55%, and total N 7.45% [16, 29]. Research about the role of shrimp waste as a nitrogen source organic fertilizer has not been widely published. Therefore, this study aims to determine the nutrients value of shrimp waste to the uptake and uptake efficiency of nitrogen, the growth, and the yield of corn.

2. Method

Tarakan Island is at x = 569893 and y = 366739 coordinates, from November 2017 to June 2018. The land that was used for the experiment was Endoaquults type with 4.9x 3.5 m plot size. Before the experiment, pre-analysis of the soil was conducted at the location of the study at a depth of 20 cm in the form of chemical properties and soil nutrient content.

Using a randomized block design (RCBD) that consist of five treatments divided into control (K), and the addition of biochar, shrimp waste, urea, and biochar+S (T), the analysis was repeated three times
to obtain 15 experimental plots. The treatment was given one week before planting by adding 10.29 kg plot\(^{-1}\) biochar, 10.29 kg plot\(^{-1}\) shrimp waste, 669 g plot\(^{-1}\) (6.83 g plant\(^{-1}\)) Urea, and 51.6 g plant\(^{-1}\) biochar + S, and 10.29 kg plot\(^{-1}\) shrimp waste. SP36 and KCl fertilizers are given based on the recommended dose of 150 kg SP-36 ha\(^{-1}\), and 150 kg KCl ha\(^{-1}\). One week later, soil samples were taken in each experiment plot to be analyzed for chemical properties and the content of the nutrients. Analysis of chemical properties and nutrient content before and after treatment in the form of pH H\(_2\)O (1: 5, pH meter), C-organic (Walkley and Black Method) \([46]\), total N content (Kjeldahl method) \([47]\), (titration method ), CEC (NH\(_4\)Cl saturation), and P available (Bray 1 method) \([48]\). The biochar used is derived from palm shell waste which is hydrolyzed at a temperature of 500\(^{\circ}\)C, has a pH of around 8.73, and a bound carbon content of around 73.6%.

Two BISI 2 hybrid corn seeds were planted 7 cm deep. After one week, only one plant was kept alive. Harvesting was done when the plant reaches the maximum vegetative phase (56 days). The focus of this observation was the plant height, number of leaves, and dry shelled seed production. Analysis of plant tissue N content using wet destruction method (extraction with H\(_2\)SO\(_4\), and distillation), N uptake value was calculated using the formula \([49,50]\).

\[
N\text{ Uptake} (g) = \text{ Plant N content } \times \text{ weight of plant biomass} \quad (1)
\]

While the efficiency of N uptake was calculated using the formula \([34]\):

\[
\text{NUE} = \frac{(N_p\text{ uptake } - N_0\text{ uptake})}{\text{ doses of N given}} \times 100\% \quad (2)
\]

NUE is the efficiency of N uptake by corn (%), Np is N uptake by corn with treatment (g), and No is N uptake without treatment (g).

Data on chemical properties and nutrient content of soil, growth, and yield of corn, and N absorption efficiency was analyzed by using orthogonal contrast at P<0.05, SAS Version 9.3. For orthogonal contrast analysis, biochar and shrimp waste are classified as ameliorant, while urea and Biochar+S as fertilizer. The HSD test then was conducted to find out the differences between treatments and the result was 95%.

3. Results
Chemical properties and nutrient content of the soil and shrimp waste used in the study are presented in Table 1. The soil in the research sites is acid, contain K and P nutrients and showed low CEC level. The content of total nitrogen, organic carbon, base cations, and base saturation (BS) is also very low. Meanwhile, shrimp waste is 8.3 pH and alkaline, the N and organic carbon contained in it is classified as high while the P total and CEC level is moderate. Cations showed a mixed result such as Mg and Ca that is classified low in level while the total of K and Na is high and very high, respectively.

**Table 1. Chemical properties and nutrient content in the soil and shrimp waste**

| Characteristic | Unit | Soil | Shrimp waste |
|---------------|------|------|--------------|
| pH H\(_2\)O (1:5) | - | 4.1 | 8.3 |
| N-tot | g kg\(^{-1}\) | 1.9 | 65.6 |
| C-organic | g kg\(^{-1}\) | 12.4 | 33.6 |
| P-tot | g kg\(^{-1}\) | 0.8 | 11.6 |
| CEC | cmol\(^{+)\} \text{ kg}^{-1}\) | 11.2 | 21.07 |
| Av-K | g kg\(^{-1}\) | 0.15 | 7.40 |
| Av-Ca | g kg\(^{-1}\) | 0.92 | 46.4 |
| Av-Na | g kg\(^{-1}\) | 0.05 | 33.4 |
| Av-Mg | g kg\(^{-1}\) | 0.27 | 0.90 |
Table 2 shows that the addition of biochar + shrimp waste (biochar+S) significantly increased the soil pH and organic carbon compared to urea. The addition of urea tends to reduce soil pH. The CEC value on addition to shrimp waste is higher than biochar, and the biochar+S is higher than urea. The pH, organic carbon, and CEC highest were obtained on the addition of biochar+S respectively 4.7, 11%, and 29.7 cmol(+)/kg⁻¹, but its pH was still somewhat acidic. The lowest organic carbon and CEC content was obtained in controls (7.1% and 11.6 cmol (+)/kg⁻¹)

The nitrogen content in the addition of biochar+S is higher than urea fertilizer, and the nitrogen content in the addition of shrimp waste is higher than biochar. The order of nitrogen content in the addition treatment is the control of biochar <urea <shrimp waste <biochar+S. The available P content is increased in the application of biochar, shrimp waste, and biochar+S. The highest content of P-available was obtained from the addition of biochar+S of 5.8 mg kg⁻¹. The addition of urea, shrimp waste, and biochar+S increases the K-available, while biochar significantly decreases K-available. The content of K-available highest was obtained in shrimp waste at 88.0 mg kg⁻¹, while the lowest was urea, 37.4 mg kg⁻¹.

The addition of biochar+S had a significant effect on plant height for 56 days, while the number of leaves was not significant. The addition of shrimp waste, biochar, urea fertilizer, and biochar+S significantly increased dry shell corn production per hectare. The addition of shrimp waste ameliorant resulted in higher significantly dry shelled corn production per hectare compared to the addition of biochar. The highest dry shelled corn production per hectare is obtained from the addition of biochar+S of around 10.6 tons. N uptake and efficiency of N uptake by corn on the addition of ameliorant shrimp waste is higher than the addition of biochar, and the addition of biochar + S is higher than the addition of urea. The highest uptake and efficiency of corn uptake was obtained with the addition of biochar + S, each 139.3 kg ha⁻¹ and 35.0%, with an increase in N absorption efficiency of around 24.8%.

**Table 2.** Effect of addition of biochar and shrimp waste on chemical properties and soil nutrient content, growth and yield of maize, and efficiency of N uptake by corn

| Comparison Group | pH   | OC   | N-tot | CEC cmol (-) | Av-P (mg kg⁻¹) | Av-K cmol (+) kg⁻¹ | Plant height of leaves (cm) | Number of leaves | Dry shell yield (t ha⁻¹) | N Uptake (kg ha⁻¹) | N Uptake efficiency (%) |
|------------------|------|------|-------|--------------|----------------|------------------|--------------------------|-----------------|-------------------------|----------------------|--------------------------|
| Cvs T Control    | 4.3  | 7.1* | 3.4   | 11.6*        | 3.4*           | 46.1             | 190*                    | 11.3            | 6.8*                    | 26.9*                |                          |
| Treatments       | 4.4  | 10.1 | 5.3   | 24.7         | 5.2            | 68.2             | 217                     | 12.9            | 8.4                     | 81.4                 |                          |
| A vs F Ameliorants | 4.4  | 10.4 | 5.2   | 24.5         | 5.8            | 62.7*            | 217                     | 13.0*           | 8.0*                    | 63.7*                | 39.9                     |
| Fertilizers      | 4.5  | 9.8  | 5.5   | 24.9         | 4.6            | 73.7             | 217                     | 12.8            | 8.8                     | 99.2                 | 33.9                     |
| B vs S Biochar   | 4.4  | 10.3 | 4.3*  | 20.9*        | 5.9*           | 37.4*            | 209*                    | 12.7            | 7.2*                    | 29.4*                | 55.1*                    |
| Shrimp waste     | 4.3  | 10.5 | 6.1   | 28.1         | 5.6            | 88.0             | 225                     | 13.3            | 8.7                     | 98.0                 | 24.9                     |
| Urea Vs Biochar+S | 4.2* | 7.9* | 4.6*  | 20.0*        | 3.4*           | 75.3             | 208*                    | 12.3            | 7.1*                    | 59.0*                | 32.8*                    |

Description: C is control; T is treatments added ameliorants (A), and fertilizers (F); Ameliorants is biochar (B), and shrimp waste (S); Fertilizers are Urea, and biochar+Shrimp waste (Biochar+S). The value followed by the same superscript was not significantly different according to the orthogonal contrast test at the 5% significance level, in each comparison group
4. Discussion

The results of the soil characterization showed that the land was classified as marginal land that had limitations in its use, such as chemical properties and low natural fertility. To improve the chemical properties and soil fertility, it can be done by adding shrimp waste, especially to meet the nitrogen requirements for plants. Shrimp waste contains various nutrients with relatively adequate amount [14, 15, 29].

High total N content in shrimp waste so that it is very good to be a nitrogen source of organic fertilizer. The addition of biochar+S increased soil pH because biochar and shrimp waste had pH that is classified as alkaline respectively 8.7 and 8.3 and contained base cations which became a-ready-to-use nutrients for plant plants. It also contained calcite minerals (CaCO₃) which donated -OH which caused an increase in soil pH. The addition of urea seemed to reduce the pH of the soil due to the reaction and dynamics of urea which was quickly transformed shortly after application. During the oxidation process, ammonium was changer to nitrite will produce H⁺ ions which are the source of soil acidity (15, 43, 51).

The addition of biochar+S increased soil organic carbon content. This was closely related to the amount and type of organic carbon in the material supplied. Biochar contains carbon which was resistant to weathering, around 736 g kg⁻¹, while carbon in shrimp waste was dominated by labile carbon, which was vulnerable to the decomposition process. The interaction between biochar and shrimp waste in increasing soil organic carbon showed that the biochar was able to improve the structure and function of organic matter came from the shrimp waste by decreasing shrimp waste decomposition rate. Biochar caused an increase in organic carbon in the soil by negative surface charges which consequently resulted in the very slow decomposition process. The high content of organic carbon in the soil can produce greater cation exchange capacity [25, 30, 31].

Shrimp and biochar waste have the same role in increasing the CEC of the soil. Shrimp waste has a fairly good CEC around 21.1 cmol (+) kg⁻¹, while the biochar has a phenolic aromatic functional group with a high enough intensity, has a surface area, and total volume that is dominated by micro and mesopores. High cation exchange capacity is resulting from a larger surface area and a higher charge density of surface unity [15, 29, 43].

The high content of potassium-available in shrimp waste applications, because shrimp waste is a source of K elements around 0.74%. The process of mineralization of shrimp waste will produce nutrients available to plants, one of which is potassium. Aside from being a source of nutrients, especially nitrogen (65.6 g kg⁻¹), shrimp waste with biochar (biochar+S) also contributes to functional groups such as carboxyl (COOH) and hydroxyl (OH-) which can play a role in nutrient retention so as to reduce nutrient losses of nitrogen and potassium so that its availability becomes increased [42,52]. In addition, these functional groups can chelate the element Al in the soil that binds P (Al-P) causing P to become loose and available to plants.

In general, the height and number of leaves at the plantation at the addition of urea did not increase, this indicates that urea was not able to support the availability of good nutrients for plants, because urea was unstable, quickly decomposes into NH₄⁺ and NO₃⁻. Nitrogen nutrients in the form of NH₄⁺ and NO₃⁻ experienced a lot of leaching because they were not absorbed by soil surface particles. The soil used has low CEC and organic carbon, which cause the available N cannot be absorbed. This was confirmed from the results of the analysis of soil nitrogen content, that the nitrogen content at the addition of urea was not significantly different from the control.

Growth in plant height and number of leaves significantly increased with the addition of biochar + shrimp waste because it contained nitrogen nutrients, and was able to provide it slowly and gradually. Nitrogen nutrient retention by organic functional groups and biological activities, within a certain period of time, would gradually meet the needs of corn plants as it started a synergy between biochar with shrimp waste (biochar + S) because it would increase the availability of nitrogen nutrients [12, 27, 49].

Giving optimal nitrogen can increase the growth rate and increase the number of leaves. The number of leaves affects the growth process and yield of plants because the leaves are the place of photosynthesis to produce the energy needed and will be used for the plant growth process both vegetative and
generative. In addition to sources of nutrition, shrimp waste could also support the life of microorganisms that help in the dissolution of phosphate to plants.

The agronomic output of corn is largely determined by soil quality, namely the capacity of the soil to support a number of agronomic and environmental functions, such as the availability of nutrients to support agronomic productivity. Corn seed production reflects the occurrence of photosynthetic accumulation during the process of photosynthesis which is supported by the availability of nutrients in sufficient quantities and types. The addition of biochar + shrimp waste is able to provide sufficient nutrients in terms of quantity and type, especially nutrients N, P, and K, which stimulate the process of photosynthesis and plant metabolism running smoothly [50]. During growth, absorbed nitrogen will accumulate in the leaves, stems, and roots. Root development is very sensitive to variations in the supply and distribution of nutrients in the soil. Photosynthesis is produced a lot and accumulates to form seeds. Phosphorus (P) plays a role in flowering because phosphorus is needed in the formation of nucleoproteins (nuclei) in seeds and fruit, fruiting, and flowering.

The results of this study indicated that the addition of biochar + shrimp waste (biochar + S) can maximize the availability of nutrients continuously during the growth period so that the corn plant still got a sufficient supply of nutrients during the growth period. The increase in nitrogen efficiency might be caused by increased nutrient retention of N by the soil component, reduced washing, volatilization, and denitrification after the addition of biochar with NH$_4^+$ based fertilizers and organic matter [41, 53]. Biochar + shrimp waste formulation can optimize nitrogen management in sustainable corn cultivation while controlling pollution and poisoning materials. An increase in the efficiency of nitrogen uptake can minimize nitrogen nutrient losses both through washing and through evaporation of nitrogen [27, 31, 54]. Corn plants can absorb nitrogen nutrients optimally at application of biochar + shrimp waste, which is equal to 139.3 kg ha$^{-1}$.

Shrimp waste had high a pH and it contributed to the form change of nitrogen from ammonium to ammonia while immobilization occurs when microorganisms cannot form nitrogen and only get it from shrimp waste. Also, shrimp waste was is added with biochar also provides sufficient carbon as a source of energy for microorganisms, and nitrogen for protein synthesis, so that the activity of microorganisms increased. Increased activity of microorganisms will help plants absorb nutrients needed [27, 55]. The microorganisms will break down organic compounds into inorganic compounds that are available and can be uptake by corn [49].

Based on the Bissi 2 maize specification, the average dry shell yield is around 8.9 t ha$^{-1}$, and the potential yield of dry shelling is around 13 t ha$^{-1}$, while the production of dry shell yield obtained in this study was 10.56 t ha$^{-1}$. This situation shows that the addition of biochar+S can increase the production of corn approaching production according to specifications.

5. **Conclusions**
The addition of biochars + shrimp waste (biochars + S) can improve the chemical properties of marginal soils and increase the supply of nutrients for Corn. The results showed that the application of biochar+shrimp was able to increase soil pH (4.9 out of 4.3), N-total is 85%, OC is 66.2%, CEC is 1.5 times the initial CEC, plant height and a number of leaves at 56 days respectively 225 cm and 13 sheets, and Nitrogen uptake efficiency around 24.8% with a dry shell yield of around 10.6 t ha$^{-1}$. Biochar and biochar+shrimp waste both increased P-available (4.8 out of 3.4 mg kg$^{-1}$), whereas K-available increased in shrimp waste applications (88 of 46.1 mg kg$^{-1}$). The addition of biochar + shrimp waste (biochar + S) is recommended for corn farming in marginal soils.

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