Foliar application of micro cattle bone ash in increasing growth and yield of sweet corn (Zea mays saccharata Sturt.)

Mulyono* and T Hidayat
Agrotechnology, Faculty of Agriculture, Universitas Muhammadiyah Yogyakarta, Indonesia.

*E-mail: mulyonosimo@gmail.com

Abstract. Cattle bone ash contains high calcium and phosphor that can be used as foliar fertilizer. The foliar application requires particles whose size must be smaller than the stomatal size. The study is expected to increase the growth and the production of sweet corn by applying cattle bone ash to sweet corn through foliar application. The experiment was conducted in a complete randomized design with five treatments; without cattle bone ash application, 0.1 %, 0.2 %, 0.3 %, and 0.4% of cattle bone ash concentration. Cattle bone ash dominated with particles smaller than stomatal size and contained high calcium, oxygen and phosphor with little of sodium and magnesium. The result showed that 0.3% application of micro cattle bone ash could enhance leaves area, root dry weight, net assimilation rate, ear weight, and 100 kernels weight of sweet corn.

1. Introduction

Agricultural practices use a large amount of phosphor fertilizer, which is manufactured from a non-renewable resource, phosphate rock [1]. Scientist predicted that in 2035 demand of phosphate rock will exceed its supply [2]. Therefore, alternative source of phosphor should be investigated. Various sources of organic matter have been used as a substitute for phosphate rock as fertilizer such as cattle bones [3]. The raw bone must be converted to ash by combustion at 100°C [4] or 250°C or higher to remove the organic matrix to produce fertilizer [5]. Bone ash generally contains 53 % calcium oxide and 42 % diphosphorus pentoxide [6]. Bones contain a higher concentration of phosphorus than commercial fertilizer from phosphate rock [3]. The standard commercial fertilizer only contains 36% diphosphorus pentoxide.

High phosphor fertilizer in bone ash will be useless when applied to soil due to strong bonds between phosphorous with aluminum and iron in acidic soil and same bonds with calcium and magnesium in alkaline soil [7]. Generally, phosphor fertilizer only has 10-25 % effectiveness [8]. To increase the effectivity of fertilizer, various technology has been introduced, and one of them is the application of foliar application. The foliar application requires particles whose size must be smaller than the stomatal size. Thus, Ball mill machine is recommended to be utilized to reduce the size of the particle and commonly used in nanotechnology. The smallest size of stomata is Rhus copallium with size of 25 µm, and the largest is Horneophyton lignieri with size of 20,700 µm [9].

Therefore, the application of micro cattle bone ash has been done to increase plant growth and yield. Sweet corn is used as the material tested in this study, since it becomes one of the most popular vegetables in the world [10]. The similar study has been done by application of meal and bone meal in
springs barley [11]. In present study, the research we evaluated on sweet corn with micro particle size and foliar application.

2. Materials and Methods
The experiment was conducted at the Greenhouse of Faculty of Agriculture, University Muhammadiyah Yogyakarta from October 2018 to January 2019. The research was arranged in completely randomized design consisted of five level concentrations of foliar application of Cattle bone ash, i.e 0%, 0.1%, 0.2%, 0.3% and 0.4%. All treatments were planted on 15 polybags with 12 kg absolute dry weight of soil for each polybag with a mixture of fertilizer in dose 180 kg/ha N, 120 kg/ha P₂O₅, and 120 kg/ha K₂O.

2.1. Preparation of the cattle bone ash
The cattle bones were collected from garbage derived from various restaurants in Yogyakarta. The cattle bone ash was made by modifying the technique used by Bahrololoom et al. [6]. The fat, the meat, and other organic components were burned by applying direct flame. After that, the bone was placed in the muffin furnace with 800°C for five hours to create a white granular bone ash. Afterward, granular bone ash placed on hammer mill to created white ash powder. White ash powder is placed in a ball mill with the addition of water and small iron ball with ratio 2:1:5. The water was removed using an oven at 300°C. The size of the particle was analyzed using Scanning Electron Microscopy (SEM), while Energy disperse X Ray Spectroscopy (EDXS) was used to analyze the distribution of particle. Samples were placed to a sample stage with carbon tape that can transmit electric flow. Images were taken at 1500x magnification. The X-rays were captured at an angle of 35.73° for 30 seconds.

2.2. Application of the cattle bone ash
The foliar application is applied by diluting cattle bone ash on 1 liter of water. The amount of cattle bone ash depends on treatment concentration. The solution is sprayed three times in vegetative phase (2, 3, and 4 weeks after planting) and two times in generative phase (6 and 7 weeks after planting). The data were observed on growth parameter such as leaves area (cm²) on the 10th week after planting (WAP), Net assimilation rate (g/dm²/week) at 2-5 WAP, and yield components such as root dry weight (g), ear weight (g), and 100 kernel weight (g) at 10 WAP. Net Assimilation Rate (NAR) was calculated using Vernon and Allison [12] formula as described as followed:

\[
NAR \ (g \ [dm^2]^{-1} \ weeks^{-1}) = \frac{W_2-W_1}{T_2-T_1} \times \frac{lnLa_2-lnLa_1}{La_2-La_1}
\]

The data obtained were analyzed using ANOVA at 5% of significance level and mean comparisons were determined through Duncan’s Multiple Range Test (DMRT) at 5% significance level.

3. Results and Discussion
Particle size becomes one of the requirements of successful application through foliage. Particles must have smaller size than aperture of stomata [13]. Based on SEM analysis the smaller size of Cattle bone ash resized using ball mill was 0.118 µm, meanwhile the largest size is 39.4 µm. However, 98.7% was dominated by particle of size below 1.2 µm (Fig. 1). This size was smaller than corn stomata aperture which is around 35 µm [14]. The particle size which is smaller than stomata aperture creates high possibility in absorption of nutrient from cattle bone ash through stomata. Although absorption of nutrient by leaves can be through various organs, stomata plays major role in absorption through foliage [15].

Based on EDXS analysis, cattle bones ash dominated with calcium, oxygen and phosphor with a little contain of sodium and magnesium (Fig. 2). Cattle bones ash contain 42.8% calcium, 38.8%
oxygen, 16.85% phosphor, 1.08% sodium and 0.71% magnesium. Generally, the formula of bones ash is $\text{Ca}_5(\text{OH})(\text{PO}_4)_3$. Oxygen becomes one of dominant element because major compound in the form of oxides [16]. Ikumapayi and Akinlabi [16] stated that X-ray Fluorescence (XRF) of cow bone powder contain 45.06% $\text{CaO}$ and 34.6% $\text{P}_2\text{O}_5$, meanwhile EDXS analysis of cow bone powder contain 18.3% calcium, 7.5% phosphor, 0.4% natrium, and 0.3% magnesium.

![Figure 1. Frequency of particle size of cattle bones ash based on SEM analysis.](image)

Application of cattle bones ash at any rate between 0.1%-0.4% could enhance root dry weight and leaves area of sweet corn at 5 WAP (Table 1). Sharma [17] stated that phosphorus fertilizer application could enhance root dry weight and leaves area. Furthermore, Sharma [17] explained that phosphor plays a major role in cell division and multiplication as the main part of the cell wall. The function of phosphor in the cell wall support by calcium, which is highly contained in cattle bone ash.

| Treatment | Leaves Area (dm$^2$) | Root Dry Weight (g) | Ear Weight (g) | 100 Kernels Weight (g) | NAR 2-5 (g (dm$^2$)$^{-1}$ week$^{-1}$) |
|-----------|----------------------|---------------------|----------------|------------------------|---------------------------------------|
| 0%        | 27.96 b              | 5.97 c              | 90.82 b        | 21.33 c                | 37.01 b                               |
| 0.1%      | 44.89 a              | 10.09 ab            | 179.46 a       | 25.67 b                | 63.79 a                               |
| 0.2%      | 34.82 ab             | 10.22 ab            | 196.13 a       | 24.95 b                | 62.87 a                               |
| 0.3%      | 45.44 a              | 12.09 a             | 259.53 a       | 28.92 a                | 71.04 a                               |
| 0.4%      | 32.00 ab             | 9.61 b              | 189.61 a       | 24.00 b                | 63.92 a                               |
| CV        | 19.05                | 11.73               | 25.52          | 4.66                   | 21.82                                 |

Mean values within a column followed by the same letters indicated non significantly different as determined by DMRT at $\alpha = 5%$.

Application of cattle bone ash through foliar with concentration of 0.3% could enhance leaves area by 62% at 5 WAP. It’s leads to increasing net assimilation rate by 91% at period 2 until 5 WAP compared to without application of foliar Cattle Bone ash (Table 1). Watson [18] explained that photosynthetic system size, in this research is leaves area, could affect net assimilation rate.
Furthermore, leaves area describe photosynthetic capacity, while net assimilation rate describes photosynthetic efficiency. Calcium that contains in cattle bone ash could enhance photosynthesis by modulating the activity of ATP-ADP and also regulating chloroplast NAD$^+$ [19]. Phosphorus plays a significant role in the structure of ATP-ADP enzymes. High efficiency shown in sweet corn applied with cattle bone ash leads to higher ear weight. Application of 0.3% of cattle bone ash could enhance ear weight up to 185% compared to without application of cattle bone ash (Table 1). The assimilate produced from photosynthesis stored in sink and the economical sink in sweet corn is ear.

4. Conclusion
The micro cattle bone ash with dose 0.3% through foliar could enhance growth of sweet corn based on leaves area, dry weight and net assimilation rate. This dose also could enhance yield of sweet corn based on 100 kernels weight. However, the aspect of physiological and metabolism need to be evaluated to make sure the use of this fertilizer.

References
[1] Siebers N and Leinweber P 2013 *J. Environ. Qual.* **42** 405.
[2] Cordell D, Rosemarin A, Schröder J J and Smit A L 2011 *Chemosphere* **84** 747–58.
[3] Simons A, Solomon D, Chibssa W, Blalock G and Lehmann J 2014 *Nat. Geosci.* **7** 3–3.
[4] Zakaria Z and Ham H 2013 *J. Teknol.* **66**.
[5] Morgulis S 1931 *J. Biol. Chem.* **93** 455–66.
[6] Bahruloloom M, Javidi M, Javadpour S, Ceram J 2009 *J. Ceram Process Res.* **10** 129–38.
[7] Mehrvarz S, Chaichi MR. 2008 *Am. J. Agric. Environ. Sci.* **3** 855–60.
[8] Haghab R H, Kotp Y H and Eissa D 2018 *J. Adv. Pharm. Educ. Res.* **8** 55–67.
[9] Franks P J and Beerling D J 2009 *Proc Natl. Acad. Sci.* **106** 10343–7.
[10] Hallauer A R 2001 *Specialty corns* (Roca Baton, FL: CRC Press).
[11] Nogalska A and Zelawska M 2013 *Plant Soil Env.* **59** 575–80.
[12] Vernon A J and Allison J C S 1963 *Nature* **200** 814
[13] Li C, Wang P, Lombei E, Cheng M, Tang C and Howard D L 2018 *J. Exp. Bot.* **69** 2717–29.
[14] Zheng Y, Xu M, Hou R, Shen R, Qiu S and Ouyang Z 2013 *Ecol. Evol.* **3** 3095–111.
[15] Fernandez V, Sotiropoulos T and Brown P 2013 *Foliar Fertilization* *Scientific Principles and Field Practices* (Paris, France: International Fertilizer Industry Association).
[16] Ikumapayi O M and Akinlabi E 2018 *Proc. Int. Conf. Indust. Eng. Oper. Manage.* 2050–8.
[17] Sharma A. 2002. *Bio-Fertilizer for Sustainable Agriculture* (India: Agrobios Indian Publications).
[18] Watson D J 1958 The Dependence of Net Assimilation Rate on Leaf-area Index *Annals of Botany* (Oxford, UK: Oxford University Press)
[19] Brand J J and Becker D W 1984 *J. Bioenerg. Biomembr.* **16** 239–49.