Utilization of fly ash - bottom ash, compost and arbuscular mycorrhizal fungi on growth of crops

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Abstract. This study examines the effectiveness of fly ash-bottom ash (FABA) from Suge Steam Power Station, Belitung Island, Indonesia. FABA will be formulated with compost and arbuscular mycorrhizal fungi (AMF), as Komfaba an ameliorant for a source of nutrition for the growth of corn, eggplant, and tomato. The study was carried out in a greenhouse experiment by applying compost and FABA in three comparisons, ie 75:25, 50:50 and 25:75; two doses of Komfaba 1250 g/pot and 2500 g/pot; and two doses of AMF 2.5 g/pot and 5 g/pot. Plants growth were observed until the vegetative phase and analyzed the number of mycorrhizal infections in plant roots. In general, Komfaba composed of compost:FABA = 75:25, at a dose of 2500 g/pot and AMF 2.5 g/pot produced significant increase in few growth parameters (plant height, shoot fresh weight, root fresh weight, and root length) of corn, eggplant and tomato. Fly ash-bottom ash can be used as a soil amendment agent and provides better results when combined with compost and arbuscular mycorrhizal fungi.

1. Introduction
Fly ash is produced as a result of coal combustion in steam power station and discharged in ash dumping areas. Combustion of bituminous and sub-bituminous coal and lignite for generation of electricity in steam power plants produces solid wastes such as fly ash (FA) and bottom ash (BA). Nowadays FA and BA disposal into the environment is one of the major concerns in Indonesia including in Belitung Island. From coal combustion, about 5% of solid pollutants are generated in the form of FABA, of which about 10 to 20% is BA and about 80 to 90% is FA of the total ash produced [1]. Coal combustion produces pollutants around 5% consisting of FABA, with FA dominance around 90% and BA 20% of the total combustion produced [1]. According to Adriano et al. [2], the several sources of micronutrients such as phosphorus, magnesium, sulfur, potassium and calcium can be found in FA, but deficient in nitrogen and carbon [3]. This deficiency may be overcome by adding various organic substrates, one of them is compost.

Compost serves as the top layer to overcome nutrient barriers for plant growth [4]. One of the mechanism of compost when it is mixed with FA, which is to control the presence of metal in the soil by means of precipitation, chelation and adsorption [5,6,7,8,9,10]. Soil improvement with the addition of compost is believed to be accelerated by applying biotechnology. One of the biotechnology applications is the use of Arbuscular Mycorrhiza Fungi (AMF). AMF is useful as a biological agent that can increase nutrient absorption and plant growth and 90% able to associate with various plant
species [11,12]. In addition, AMF is able to access inorganic and organic nutrient sources in the soil [13].

The alkaline nature of FABA has its use as amendment in agricultural fields. Therefore, utilization of fly ash, bottom ash combine with compost and AMF, as an ameliorant, will be useful for improving soil quality and will be deriving agronomic benefits for growth of corn, eggplant dan tomato.

2. Methodology

The research was carried out at the greenhouse of the Department of Soil Science and Land Resource, Faculty of Agriculture, IPB University, Indonesia. The crop plants selected for study include corn (Zea mays), eggplant (Solanum melongena), and tomatoes (Solanum lycopersium). Experiments were conducted in pots (30 cm diameter, 8 kg capacity) with 13 treatments of Komfaba. The Komfaba were formulated of 3 factors. The first factor is a mixture of compost and FABA, K1 (compost:FABA=75:25), K2 (compost:FABA=50:50), and K3 (compost:FABA=25:75). The second factor was the ameliorant doses, D1 = 1250 g/pot and D2 = 2500 g/pot. The third factor was AMF doses, M1 (5 g/pot) and M2 (2.5 g/pot).

Characteristics of soil, compost and FABA used in the experiments are presented in Table 1. Three replicates for each treatments were maintained along with control for each crop. The basic fertilizers were given at the beginning of planting, 2 weeks after planting (WAP) and 4 WAP. The fertilizers given were Urea, SP-36 and KCl. Corn seeds were sown in pots at a depth of 3 cm. Three seedlings of eggplant and tomato were planted in a pot. Pots were placed in unshaded area and uniformly watered throughout the experiment to maintain equal field capacity. After 15 days of sowing/transplantation of seed/seedling, plants were thinned to one plant in 39 pot for each plants. Plants were harvested at 35 Days After Transplanting (DAT).

3. Result and Discussion

3.1 Chemical Properties of Soil, Compost and FABA

The basic material analysis was carried out at the initial stage of the research to determine the characteristics of each material, which is presented in Table 1.

| Parameters                  | Unit | Soil  | Compost | Fly ash | Bottom ash |
|-----------------------------|------|-------|---------|---------|------------|
| pH                          | -    | 4.68  | 7.1     | 11.1    | 8.3        |
| Organic carbon              | %    | 1.26  | 32.26   | 0.17    | 0.29       |
| Total-P                     | ppm  | 6.99  | 27.82   | 5.42    | 3.89       |
| Cation exchange capacity    | cmol(+) kg⁻¹ | 9.00 | 90.40   | 3.70    | 3.50       |
| Exchangeable-Mg             | cmol(+) kg⁻¹ | 0.11 | 17.00   | -       | -          |
| Exchangeable-Ca             | cmol(+) kg⁻¹ | 0.30 | 30.60   | -       | -          |
| Exchangeable-Na             | cmol(+) kg⁻¹ | 0.07 | 30.64   | -       | -          |
| Exchangeable-K              | cmol(+) kg⁻¹ | 0.05 | 17.00   | -       | -          |

P = Fosfor; Mg = Magnesium; Ca = Calsium; Na = Natrium; K = Kalium

Soil was acid (pH 4.68), whereas FA and BA were alkaline (pH 8.3 - 11.1).

3.2 The effect of Komfaba on soil reaction

Application of all treatments increased the soil pH (Figure 1), but there were no significance difference among the treatments. FA is capable of being a material that can neutralize soil acidity and as a source of nutrition for plants [14]. This is in accordance with the opinion of Matsi and Keramidas [15] that FA can be used as an agent in liming acid soils and has an effect on improving soil physical properties and increasing yields [16].
The effect of Komfaba on the growth of corn, eggplant and tomato

The effect of plant growth can be seen in Figure 2. Application of the Komfaba had significant effect on germination of corn and seedling growth of eggplant and tomato. Significant effect of Komfaba application was noticed for plant height of corn, eggplant, and tomato (Figure 2). Maximum height (128.3 cm in corn, 3.4 cm in eggplant and 75.7 cm in tomato) was recorded in K1D2M2 for corn and tomato, K1D1M2 for eggplant at 5 WAP. In general, increase in plant height was recorded up to K1D2M2 application after that a reduction in plant height was observed (Figure 2, 3, 4). Similarly, to corn, eggplant and tomato shoot- and root fresh weight. The same results also shown by [16] in the dry weight and yield of corn, by [17] in tomato.

Amendment of FABA up to 25% improved the growth of the three crops, whereas the gradual decline in plant growth parameters was found from 50% to 75% FABA in Komfaba, whereas higher concentration of FABA had deleterious effect on fresh and dry weight and root length of the crops. This adverse effect was attributed to salinity caused by higher levels of sulphate, chloride, carbonate and bicarbonate in FA [18].

Figure 1. Soil pH.

Figure 2. The height, shoot and root fresh weight of corn 5 WAP.
3.4 Effect of Komfaba on AMF infections

Observed root infections of each crop are presented in Figure 5, 6 and 7, while the root length can be seen in Figure 6. The results of measuring the percent colonization of AMF in plant roots were calculated based on the presence or absence of mycorrhizal structures in the roots (root infection) that had been stained with Trypan Blue showing AMF colonization, namely spores, hyphae and vesicles contained in plant roots with the percentage of AMF spores very varied from each treatment given to the plant. The most number of root colonization found in eggplant reached 97% in K1D2M1 treatment (Figure 7). Where the treatment is a ratio of 75% compost and 25% FABA. Although there have been many studies discussing how the addition of compost can affect AMF colonization, there are still few studies that discuss the impact on the function of AMF on these additions. (Caravaca et al., 2003; Puschel et al., 2008; Roldan et al., 2006).
**Figure 5.** Mycorrhizal infections on the roots of corn on top image, eggplant in the middle and tomatoes in bottom at 5 WAP (magnification 100x).

**Figure 6.** Differences in root length of corn dan tomatoes.

**Figure 7.** The results of Mycorrhizal colonization observations on corn, eggplant and tomato roots.
4. Conclusion
In this study, Komfaba was found beneficial for the cultivation of corn, eggplant and tomato crops and showed immense potential to improve their growth. The greenhouse experiment conducted showed that the application of K1D2M2 formulation (compost:FABA=75:25, 2500 kg Komfaba/pot, and 5g/pot AMF experienced the best growth compared to other formulations. Thus, the application of Komfaba has the potential not only for improving the crops growth but also for solving the FABA disposal problem. It is also important to investigate the possible accumulation of toxic substances in soil and plants, especially in seeds and fruits, which are directly consumed in our daily diet. Field trials also needed to find out the effect of Komfaba in crop yields.

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References

[1] Ram L C, Masto R E 2014 Fly ash for soil amelioration: A review on the influence of ash blending with inorganic and organic amendments *Earth-Science Reviews*. 128 52–74
[2] Adriano D C, Weber J, Bolan N S, Paramasivan S, Koo B J, Sajwan K S 2002 Effect of high rates of coal fly ash in soil, turfgrass and ground water quality *Water Air Soil Poll*. 139 365-358
[3] Basu M, Pande M, Bhadoria P B S, Mahapatra S C 2009 Potential fly-ash utilization in agriculture: a global review *Natural Science*. 19 1173–1186
[4] Dere A L, Stehouwer R C, Aboukila E, McDonald K E 2012 Nutrient Leaching and Soil Retention in Mined Land Reclaimed with Stabilized Manure *Journal of Environmental Quality*. 41 (6) 2001-2008
[5] Logan T J, Harrison B J 1995 Physical characteristics of alkaline stabilized sewage sludge (N-Viro soil) and their effects on soil physical properties *J. Environ. Qual*. 24 153–164
[6] Ram L C, Srivastava N K, Tripathi R C, Jha S K, Sinha A K, Singh G, Manoharan V, 2006a. Management of mine spoil for crop productivity with lignite fly ash and biological amendments *J. Environ. Manag*. 79 173–187
[7] Ram L C, Srivastava N K, Jha S K, Sinha A K 2006b Eco-friendly reclamation of mine spoil for agro-forestry through fly ash and biological amendments *Proceedings of the 23rd Annual International Pittsburgh Coal Conference Session*. 52 pp. 1–25
[8] Ram L C, Srivastava N K, Jha S K, Sinha A K, Masto R E, Selvi, V A 2007b Management of lignite fly ash through its bulk use via biological amendments for improving the fertility and crop productivity of soil. *Environ. Manag*. 40 438–452
[9] Zhang H, Sun L, Sun T, 2008a Solubility of ion and trace metals from stabilized sewage sludge by fly ash and alkaline mine tailing *J. Environ. Sci*. 20 710–716
[10] Chen Y Q, Luo Z, Hills C, Xue G, Tyrer M 2009 Precipitation of heavy metals from waste water using simulated flue gas: sequent additions of fly ash, lime, and carbon dioxide. *J. Water Res*. 43 2605–2614
[11] Setiadi Y 2007 Working with mycorrhizae in the tropics. Second Mycorrhizal National Congress. Accelerating the Socialization of Mycorrhizal Technology to support Forestry, Agriculture and Plantation Revitalization, Bogor 10 p. (in Indonesian)
[12] Smith S E, Read D J 2008 Mycorrhizal Symbiosis. Third edition: Academic Press. Elsevier Ltd. New York, London, Burlington, San Diego. 768 p
[13] Read D J, Perez-Moreno J 2003 Mycorrhizas and Nutrient Cycling in Ecosystem *New Phytologist*. 157 475-492
[14] Taylor E M, Schumann G E 1988 Flyash and lime amendment of acidic coal soil to aid revegetation. *J Environ Qual*. 7 120–124
[15] Matsi T, Keramidas V Z 1999 Flyash application on two acid soils and its effect on soil salinity, pH, B, P and on ryegrass growth and composition. *Environ Pollut.* 104 107–112

[16] Ghuman G S, Menon M P, Chandra K, James J, Adriano D C, Sajwan K S 1994 Uptake of multi-elements by corn from fly ash compost amended soil *Water Air Soil Pollut.* 72 285–295

[17] Khan M R, Khan M W 1996 The effect of fly ash on plant growth and yield of tomato *Environ. Pollut.* 92(2) 105–111

[18] Singh L P, Siddiqui Z A 2003 Effects of flyash and Helminthosporium oryzae on growth and yield of three cultivars of rice. *Bioresour Technol.* 86 73–8

[19] Caravaca F, Figueroa D, Azcon-Aguilar C, Barea J M, Roldan A 2003 Mediumterm effects of mycorrhizal inoculation and composted municipal waste addition on the establishment of two Mediterranean shrub species under semiarid field conditions. *Agric. Ecosyst. Environ.* 97 95-105

[20] Puschel D, Rydlova J, Sudova R, Gryndler M 2008 Cultivation of flax in spoilbank clay: mycorrhizal inoculation vs. high organic amendments. *J. Plant Nutr. Soil Sci.* 171 872-877

[21] Roldan A, Carrasco L, Caravaca F 2006 Stability of desiccated rhizosphere soil aggregates of mycorrhizal Juniperus oxycedrus grown in a desertified soil amended with a composted organic residue. *Soil Biol. Biochem.* 38 2722-2730