Enhancement of Sandy Soil Quality Using Plant Waste

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Abstract**—** Soil is the outermost layer of the earth's crust used as a medium for plant growth and biological activity. Soil components are composed of mineral, organic matter, soil air, and liquid materials. In the mineral materials, inorganic materials are composed of a mixture of gravel, sand, silt, and clay. For this study, the effect of the introduction of certain amounts of sawdust and rice straw as Mg and Ca supply to the soil was evaluated. Sandy soil was chosen because of its lowest soil electrical conductivity (EC). Parameters of soil EC and pH are selected to determine the soil quality improvement. From a result, the soil pH and soil EC with the best formulation of 0.5% saw dust + 0.5% rice straw (*w/w*), with the highest deposition of Mg and Ca into the soil can increased the sandy soil EC up to 1.7 times in five weeks time duration. Therefore, it can be concluded that the addition of plant waste has the potential to enhance the overall quality of soil which is significant taking into consideration reduction in the land area available for agriculture activities.

Keywords**—Sandy soil, plant waste, soil electrical conductivity, pH, Malaysia.**

I. Introduction

CROP production in sandy soils is mainly limited by nutrient conditions. The main nutrient attributes, such as soil organic matter, cation exchange capacity (CEC), and N content, are significantly lower and plant nutrient availability is the most limiting factor for sandy soils than other soils [1]. As reported by [2], effect of carbon (C) source with a conclusion that carbon accretion may be limited by the low C saturation level of these sandy-structured soils may reduce priming on derived C also contribute to the sandy soil quality.

Rice is the main crop for many lowland farmers in Southeast Asia. In most areas rice has been grown as the monoculture for a long time. Malaysia is enriched with biomass resources. The main sources of biomass in Malaysia are from plantation and agricultural residues. One of the most potential and available agricultural residues is rice straw. The total paddy residue production in Malaysia is 7 million tonne per year [3].

Rice straw (RS) is the residue and the excess of production of rice that is not utilized. The waste discharged can cause environmental problems and a loss of natural resources. If the wastes can be utilized, they are no longer wastes but have become new resources. The most traditional uses of rice by-products include straw and hull for energy (production of biogas through anaerobic digestion), animal feed, building materials and paper production [4]. An attractive alternative to recycling of such waste is the compost production through microbial activity which is then mixed with the rock phosphate and ammonium sulphate to be used as an organic fertilizer [5].

As reported by [6], application of RS can improve the chemical properties and nutritional status of the soil through (i) lowering pH and its effects on nutrient availability (ii) increasing organic matter content, organic nitrogen percentage in the soil, (iii) increasing available N, P and K in treated soil, as well as the activity of both dehydrogenase and phosphatase. Biological activity of the soil is expressed as a total count of bacteria i.e. *Azotobacter* sp., phosphate dissolving bacteria (PDB), fungi and *actinomycetes*/g soil and the activity of both dehydrogenase and phosphatase.

The effect of wood ash, sawdust, ground cocoa husk, spent grain and rice bran upon root development, ash content, pod yield and nutrient status and soil fertility for okra (Abelmoschus esculentum L NHAe 47 variety) is also reported by [7].

The aim of the study reported here is to examine the effect of the use of RS compared to rice bran (RB) as a mineral or nutrient source mixed with sawdust as a carbon source to the soil pH and soil EC. The results will help the user or farmer as guideline in term of producing their own organic fertilizer to maintain the soil health.

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II. Materials And Methods

A. Characteristics of raw materials

Table 1 shows the characteristics of sandy soil used in this experimental work. By adding the agricultural waste into the soil in different formulation, then the parameters such as soil pH and soil EC as dependent variables are monitored.

In this study, magnesium (Mg^{2+}) and calcium (Ca^{2+}) are the main minerals or cation content which affects the sandy soil quality after the application of the different sources of raw materials [8][9]. Table 2 shows the results of analysis for saw dust, rice bran and rice straw with the different % of Mg^{2+} and Ca^{2+} content.

Table 1
Characteristics Of Sandy Soil

Parameters	Amount
pH	6.20
C/N ratio	9.42
Cation exchange capacity (C.E.C), m_{eq}/100g	11.20
Electrical conductivity (EC), µS	40.70
Coarse sand, %	95.00
Fine sand, %	5.00

Table II
Characteristics Of Minerals Content In Agricultural Waste

Material	Cations	Analysis Content	
		mg/L	%
Sawdust	Mg^{2+}	4.9	0.00049
	Ca^{2+}	10.0	0.00100
Rice Bran	Mg^{2+}	25.7	0.00257
	Ca^{2+}	33.0	0.00330
Rice Straw	Mg^{2+}	36.5	0.00365
	Ca^{2+}	47.0	0.00470

B. Methods

The experiment work is divided into two different tests. Firstly, the screening test on the mixtures of raw materials after application onto the sand by a quick measure of the soil EC and content of Mg^{2+} and Ca^{2+}. The preliminary combination of sand:sawdust:rice bran (RB) and sand:sawdust: rice straw (RS) with ratio 1:1:1 are prepared.

Secondly, the combination of the mixtures was carried out by one factor at a time experiment (OFAT), where the moisture (30-40% humidity), the amount of sand (250 g, 500-700 µm) used and the varied percentage of the saw dust (500 µm), rice bran (500 µm) and rice straw (500 µm) applied as independent variables are fixed. Then the parameter of soil pH and soil EC as dependent variables are measured with the ratio of sandy soil: water (1:5) in a five day duration by sampling the soil every day [10]. All the experiments are in anaerobic condition (closed system).

III. Result And Discussion

Table 3 shows the results of screening test of each raw material related to the soil EC, Mg^{2+} and Ca^{2+} content. From the analysis , rice bran (RB) gave the highest soil EC and rice straw (RS) gave the highest Mg^{2+} and Ca^{2+} content. After the combination of agricultural wastes with the ratio of sand: sawdust: RB/RS which is 1:1:1, the combination of sand + sawdust + RB still gave the highest soil EC compared to the the combination of sand: sawdust: RS which gave the highest Mg^{2+} and Ca^{2+} content. With these screening test results, as an indicator certain formulation is good for soil EC and another formulation is good in term of nutrients transfer to the sandy soil [11].

Table III
Characteristics Of Different Formulation Of Agricultural Waste Effect On The Sandy Soil Conductivity

Material	Soil EC (µS)	Analysis Content	
		% Mg^{2+}	% Ca^{2+}
Sand	48.5	0.00005	0.00143
Sawdust	99.6	0.00049	0.00100
Rice Bran	972.6	0.00257	0.00330
Rice Straw	438.5	0.00365	0.00470
Sand + Sawdust	33.9	0.00005	0.00143
Sand + Sawdust + Rice Bran	127.3	0.00006	0.00143
Sand + Sawdust + Rice Straw	82.5	0.00007	0.00144

From Fig.1, RB 5% + SD 0.5% and RB 2.5% + SD 0.25% show the highest effect to lower the soil pH to be more acidic and consistent after 5 days of application with a pH reading of 4.6. Another formulation, RB 1% + SD 0.1% the pH readings tend to be less acidic with a soil pH of 4.60 in day 5. From Fig. 2, the highest and consistent of soil EC is achieved with the formulation of RB 5% + SD 0.5% after application in day 5. This shows that the nutrients from RB are more soluble and exchanged in the sandy soil compared to other formulations.

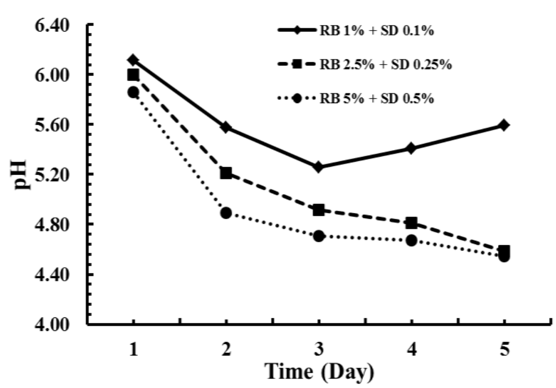

Fig 1. Effect of soil pH with different combination of RB and SD

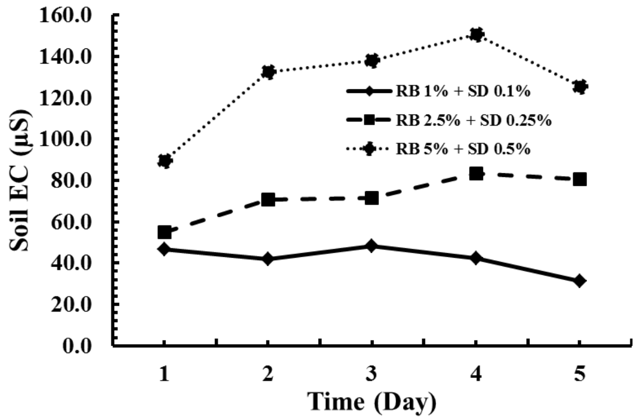

Fig 2. Effect of soil EC with different combination of RB and SD

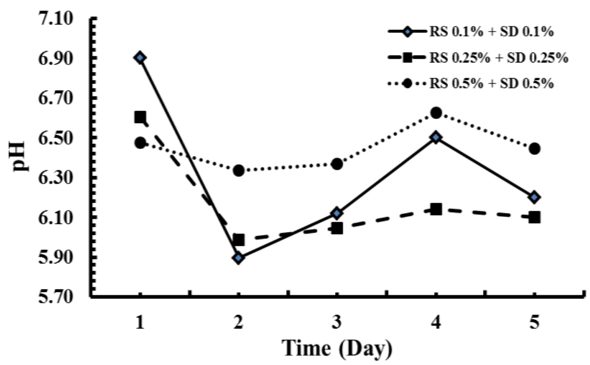

Fig 3. Effect of soil pH with different combination of RS and SD

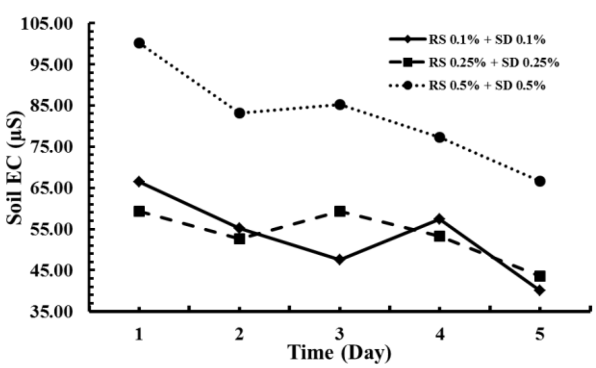

Fig 4. Effect of soil EC with different combination of RS and SD

From these application results, with RB 5% + SD 0.5% after application in sandy soil, showed the best effect on the sandy soil which turned to be more acidic and consistent to generate the highest soil EC.

From Fig. 3, the combination of RS 5% + SD 0.5% gave the results of mixtures to be more acidic and consistent in day 5 from pH 6.6 to 6.0. From Fig. 4, all the formulation is not consistent to soil EC and became less related as time increased. It can be concluded that the application of RS in the sandy soil will cause the soil to be slightly acidic but the level of acidification is not enough to balance the nutrients exchange in the sandy soil [12]. By comparing the application of RB and RS in different formulations, it can be shown that the application of RB gave more advantages compared to RS.

IV. Conclusion

In conclusion, the best RB application with formulation of RB 5% + SD 0.5% is in the slightly alkaline soil, where it can help to reduce the alkaline soil reading to close to pH 6.5, which is the best for all the nutrients in the soil for plant uptake. In the same time, this formulation can help to increase the soil EC to support the cation holding capacity in the soil.

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References

[1] S. a. Watmough, C. J. Whitfield, and M. E. Fenn, "The importance of atmospheric base cation deposition for preventing soil acidification in the Athabasca Oil Sands Region of Canada," Sci. Total Environ., vol. 493, pp. 1–11, 2014. http://dx.doi.org/10.1016/j.scitotenv.2014.05.110

[2] D. Epron, C. Mouanda, L. Mareschal, and L.-S. Koutika, "Impacts of organic residue management on the soil C dynamics in a tropical eucalypt plantation on a nutrient-poor sandy soil after three rotations," Soil Biol. Biochem., vol. 85, pp. 183–189, 2015. http://dx.doi.org/10.1016/j.soilbio.2015.03.010

[3] S. M. Shafie, H. H. Masjuki, and T. M. I. Mahlia, "Rice straw supply chain for electricity generation in Malaysia: Economical and environmental assessment," Appl. Energy, vol. 135, pp. 299–308, 2014. http://dx.doi.org/10.1016/j.apenergy.2014.08.101

[4] R. T. Rashad, "Separation of some rice straw components and studying their effect on some hydro-physical properties of two different soils," J. Environ. Chem. Eng., vol. 1, no. 4, pp. 728–735, 2013. http://dx.doi.org/10.1016/j.jece.2013.07.011

[5] S. Bunna, P. Sinath, O. Makara, J. Mitchell, and S. Fukai, "Effects of straw mulch on mungbean yield in rice fields with strongly compacted soils," F. Crop. Res., vol. 124, pp. 295–301, 2011. http://dx.doi.org/10.1016/j.fcr.2011.06.015

[6] H. El-Saied, O. a. El-Hady, A. H. Basta, C. Y. El-Dewiny, and S. a. Abo-Sedera, "Bio-chemical properties of sandy calcareous soil treated with rice straw-based hydrogels," J. Saudi Soc. Agric. Sci., pp. 1–7, 2014.

[7] E. I. Moyin-Jesu, "Use of plant residues for improving soil fertility, pod nutrients, root growth and pod weight of okra (Abelmoschus esculentum L)," Bioresour. Technol., vol. 98, pp. 2057–2064, 2007. http://dx.doi.org/10.1016/j.biortech.2006.03.007

[8] Q. a. Panhwar, U. a. Naher, O. Radziah, J. Shamshuddin, and I. M. Razi, "Bio-Fertilizer, Ground Magnesium Limestone and Basalt Applications May Improve Chemical Properties of Malaysian Acid Sulfate Soils and Rice Growth," Pedosphere, vol. 24, no. 6, pp. 827–835, 2014. http://dx.doi.org/10.1016/S1002-0160(14)60070-9

[9] Y. Koyama, R. Zhao, M. Ike, and K. Tokuyasu, "Candida utilis assimilates oligomeric sugars in rice straw hydrolysate via the Calcium-Capturing-by-Carbonation (CaCCO) process for glutathione- and cell-biomass production," Bioresour. Technol., vol. 172, pp. 413–417, 2014. http://dx.doi.org/10.1016/j.biortech.2014.08.097

[10] X. Jiang, X. Hou, X. Zhou, X. Xin, A. Wright, and Z. Jia, "pH regulates key players of nitrification in paddy soils," Soil Biol. Biochem., vol. 81, pp. 9–16, 2015. http://dx.doi.org/10.1016/j.soilbio.2014.10.025

[11] G. Kargas and P. Kerkides, "Comparison of two models in predicting pore water electrical conductivity in different porous media," Geoderma, vol. 189–190, pp. 563–573, 2012. http://dx.doi.org/10.1016/j.geoderma.2012.06.024

[12] O.-O. E. Ricardo, M.-R. L. Fernando, and T.-L. Patricia, "Evaluation of the Addition of Wood Ash to Control the pH of Substrates in Municipal Biowaste Composting," Ing. Investig. y Tecnol., vol. 15, no. 3, pp. 469–478, 2014. http://dx.doi.org/10.1016/S1405-7743(14)70355-5