The Effectiveness of Soil Ameliorant to Increase Growth and Yield of Sugarcane Planted in Ultisols at Bone Sugarcane Plantation in South Sulawesi, Indonesia

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Abstract: This research aims to know the effectiveness of soil ameliorant (compost, boiler-ash, and dolomite) and inorganic fertilizer (urea, superphosphates-36, and potassium chloride) on the growth and yield of sugarcane. Treatments designed by combinations of six factors were compost (t ha^{-1}) – boiler-ash (t ha^{-1}) – dolomite (t ha^{-1}) – urea (kg ha^{-1}) – superphospate36 (kg ha^{-1}) – potassium chloride (kg ha^{-1}). The six treatments described from the order of the factors in this combinations were (t1) 0– 0 – 0 – 300 – 200 – 100, (t2) 0– 40 – 0 – 300 – 200 – 100, (t3) 0– 40 – 1 – 300 – 200 –100, (t4) 0– 40 – 1 – 300 – 200 – 0, (t5) 6– 40 – 1 – 300 – 200 – 100, and (t6) 6– 0 – 1 – 300 – 200 – 100. The result of this study showed that by the presence of inorganic fertilizer, comparing between t5 vs t1, soil ameliorant result from the highest of all growth and yield component of sugarcane; the number of tillers (numbers per meter of row) increase from 11.20 to 15.93, stem weight (kg per stem of a plant) increase from 2.33 to 2.78, redeem increase from 6.44 % to 8.31%, and sugar production increase from 5.97 t ha^{-1} to 13.89 t ha^{-1}.

1 INTRODUCTION

The problem faced by the sugar industry in Indonesia is that land productivity is still low, so that sugar production has not been able to meet national needs (Amin, et al., 2014). One of the things that cause low sugar production are because most of the sugarcane is grown on unsuitable land. In addition, planting keprasan sugarcane that exceeded the recommendation caused the planting to be dominated by old varieties so that the quality of sugarcane produced was relatively low (Mardianto, et al., 2005).

Sugarcane production in Ultisols is lower than in volcanic and calcareous soils (Amin, et al., 2014). Based on 2015 statistical data, the average sugarcane production in Java is 68.50 tonnes ha-1, generally dominated by volcanic and calcareous soils, while Sulawesi (Bone, Camming and Takalar) is dominated by Ultisol land is only able to provide production of 32.45 tonnes. ha-1.

The low sugarcane production in Ultisol is due to the thin topsoil layer, low organic matter content, and high soil acidity. High acidity is caused by high concentrations of H^{+} and Al^{3+} in the soil solution. These conditions can cause root damage, Al^{3+} and Mn^{2+} poisoning, micronutrient deficiency, and low availability of phosphorus, nitrogen, sulfur and potassium. In ultisol land, there is also soil compaction in the topsoil layer so that the roots experience obstacles to penetrate the subsoil. The provision of repairers and fertilizers into the soil can improve the problems that exist in Ultisol.

Commonly used soil ameliorants are lime, organic matter, natural phosphate, zeolite and biochar (biological charcoal). Kettle ash is used to replace biochar because it has characteristics similar to biochar (Glasser, Zech, 2002). Biochar is natural charcoal from incomplete combustion, leaving nutrients that can fertilize the soil. If combustion takes place completely, biochar turns into ash and releases carbon (Gana, 2008). Kettle ash is produced by sugar factories in large quantities and is still the best material as solid waste. Several studies have used ash from the combustion of solid materials as waste in a factory.

Applying 4.5 t ha-1 of rice husk ash gave the highest yields on cowpeas on sandy Regosol soil; applying palm oil ashes to peatlands increases P and

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K uptake significantly; Wood ash has a liming effect between 8% -90% so that it can increase plant growth by up to 45% compared to conventional limestone (Purwono, et al., 2011). Alfalfa stem ash is a potential liming material and a source of potassium (Mozaffari, et al., 2000). Applying ash of 0.6-14.6 g kg-1 of soil to maize can increase soil pH, exchange K, Ca, Mg and P in the soil, and reduce Fe, Mn, Ni and Zn. Understanding the problems in Ultisol soil, the use of soil ameliorant and inorganic fertilizers is expected to improve the soil's physical, chemical, and biological properties to increase the growth and production of sugarcane. This study aims to assess the effectiveness of soil ameliorants (compost, kettle ash, dolomite) and inorganic fertilizers in improving sugarcane growth and production.

2 RESEARCH METHODS

2.1 Study Area

The research was carried out in the sugarcane plantation area at Arasoe Sugar Factory, Bone Indonesia. The Ultisol soil has a dusty clay texture, and the lumpy soil structure is angled, relatively firm. There is a layer of the pan (watertight) at an average depth of 20-30 cm. The study lasted 12 months.

2.2 Research Tools

Tillage using a tractor for plough, comb and water. The coordinates of the locations are recorded using the Gamin brand global positioning system. The diameter of the root is measured using a calliper. Sugarcane samples were oven-dried in the laboratory. The root length is measured using graph paper. The materials used are sugarcane cuttings, compost, kettle ash, dolomite lime, urea, superphosphate36, potassium chloride.

2.3 Research Protocol

The study was designed using a randomized block design (RBD) consisting of 6 treatments and 3 replications. The combination of treatments studied were compost (t ha-1) - kettle ash (t ha-1) - dolomite (t ha-1) - Urea (kg ha-1) - SP36 (kg ha-1) - KCl (kg ha) -1). According to the order above, there are six forms of treatment combinations tested, namely (t1) 0 - 0 - 0 - 300 - 200 - 100, (t2) 0 - 40 - 0 - 300 - 200 - 100, (t3) 0 - 40 - 1 - 300 - 200 - 100, (t4) 0 - 40 - 1 - 300 - 200 - 0, (t5) 6 - 40 - 1 - 300 - 200 - 100, and (t6) 6 - 0 - 1 - 300 - 200 - 100. Each treatment combination was repeated three times so that there were 18 treatment plots.

2.4 Research Implementation

The experimental plot was made with a size of 20 m x 30 m. Plowing is carried out to a plow depth of 30-35 cm. Soil processing is carried out in three stages, namely plowing, harrowing, and furrowing. Tillage is carried out in cross or in opposite directions using a three-eye plow pulled by a tractor with a plow capacity of 0.30-0.33 ha hour-1.

The local varieties of sugarcane seeds PSBM901 and CM47 were planted in the water 125 cm apart. Three buds were selected for sugarcane seeds to obtain uniform germination. Sugarcane seeds that have been planted in water are immediately covered with soil as thick as 5- 10 cm.

Soil ameliorants were used one time at planting, and inorganic fertilizers were used two times at planting and eight weeks after planting. At the first application, fertilizers were used along the row and below seedlings. Dosages used were 200 kg ha-1 of urea and 200 kg ha-1 of superphosphate-36. At the second application, used between rows by fertilizer applicator (Anderson, Hendrick, 1983), fertilizers were 100 kg ha-1 urea and 100 kg ha-1 KCl.

3 RESULTS AND DISCUSSION

3.1 The Effectiveness of the Soil Ameliorant

The elemental content in each of the soil ameliorant materials used can be seen in Table 1. In contrast, the nutrient input based on the content and dosage of inorganic fertilizers, compost, kettle ash and dolomite can be seen in Table 2.

Table 1. Elemental content in each material used

Material	Nutrient content (%)							CEC (cmol kg^{-1})
	c-org	N	P	K	Ca	Mg	Na	
Compost	36.42	0.03	0.32	0.53	2.22	0.55	0.37	22.20
Ash	47.32	0.35	0.37	0.63	2.54	0.71	0.44	33.16
Dolomit	-	-	-	-	40.00	-	-	-

The best input of nutrients from soil ameliorant with inorganic fertilizers is a combination of compost dosage of 6 tons ha-1, kettle ash 40 tons ha-1 and dolomite 1 ton ha-1, where the addition of organic matter into the soil is 3,022 kg ha-1, N 283 kg ha-1, P 2,580 kg ha-1 and K 2,165 kg ha-1 (Table 2).

Table 2. Nutrient input based on combination dosages of ameliorant and inorganic fertilizers

Dosages of ameliorants (t ha^{-1}) and inorganic fertilizers (kg ha^{-1})
The sequence of treatment combination (t): compost – boiler ash – dolomite – Urea – superphospates36 potassium chloride
T1 0– 0 – 0 – 300 – 200 – 100
T2 0– 40 – 0 – 300 – 200 – 100
T3 0– 40 – 1 – 300 – 200 – 100
T4 0– 40 – 1 – 300 – 200 – 0
T5 6– 40 – 1 – 300 – 200 – 100
T6 6– 0 – 1 – 300 – 200 – 100

Nutrient Input (kg ha^{-1})						
c-org	N	P	K	S	Ca	Mg
0	138	72	60	0	0	0
2528	262	2200	1912	14664	4552	5124
2528	262	2200	1912	14664	4552	5124
2528	262	2200	1852	14664	4552	5124
3022	283	2580	2165	16364	6074	6535
494	159	452	313	1700	1822	1591

3.2 Effect of Soil Enhancers on the Growth and Yield of Sugarcane

Statistical analysis used HSD showed that combinations of soil ameliorant and inorganic fertilizers have a significant effect on components of plant growth (Table 3). A complete combination of soil ameliorants and inorganic fertilizers (T5) results in the highest plant height and is significantly different compared to the other combinations.

Table 3. The effect of the combination of soil ameliorant and inorganic fertilizers on the growth of sugarcane.

Treatment combinations	Plant height (m)	Number of tillers (in one meter of row)	Stem diameter (cm)	Root length (m)
T1	2,87^{b}	11,20^{c}	2,90^{b}	18,27^{c}
T2	2,91^{b}	13,87^{ab}	2,93^{ab}	27,89^{b}
T3	2,91^{b}	14,00^{ab}	2,94^{ab}	40,62^{a}
T4	2,89^{b}	12,73^{bc}	2,91^{b}	23,77^{bc}
T5	3,01^{a}	15,93^{a}	3,00^{a}	45,10^{a}
T6	2,92^{b}	14,13^{ab}	2,94^{ab}	27,89^{b}

Means followed by the same letter in the same column are not significantly different at the 0.05 HSD level.

Soil ameliorant (compost, kettle ash, and dolomite) applied with inorganic fertilizers (urea, superphosphate36, and KCl) had a significant effect on the number of sugarcane seedlings (Table 3). However, when the treatment did not use KCl (T4 treatment), the number of tillers was not significantly different from the T1 treatment using KCl. In its application with inorganic fertilizers, single-use or a combination of soil amendments did not provide a significant difference in the number of tillers. A single treatment or a combination of two types of soil ameliorant and inorganic fertilizers has not improved soil quality compared to treatments that use a complete combination between soil ameliorant and organic fertilizers. Better soil quality is reflected in the improvement of the quality of the growing components of sugarcane. The high yield in almost all growth components in the T5 treatment indicates that inorganic fertilisers need to be combined with soil ameliorant. It is presumably because compost and kettle ash decomposition in the soil contributed to macro and micronutrients (Table 1 and Table 2) (Gana, 2011), also states that the addition of biochar similar to kettle ash into the soil, increases the availability of phosphorus, nitrogen and cation exchange capacity (CEC).

3.3 The Effect of Soil Ameliorants and Inorganic Fertilizers on Sugar Production

Stem diameter, number of tillers, and stem weight positively correlated with sugar production; sugar production positively correlated with sugar concentration. Otherwise, stem diameter had a negative correlation with sugar concentration (Sangeetha, et al., 2011). Statistical analysis showed that soil ameliorants had a significant effect on increasing sugar production.

Table 4. The effect of soil ameliorants and inorganic fertilizers on sugar prodution

Treatment combinations ti: compost – boiler ash– dolomite–urea– superphospates36 – potassiumchloride	Stems weight (kg/5 stems of sugarcane)	Stem production (tha^{-1})	Sugar rendement (%)	Sugar production (tha^{-1})
T1: 0 – 0 – 0 – 300 – 200 – 100	$11,63^{b}$	$92,60^{d}$	$6,44^{b}$	$5,97^{d}$
T2: 0 – 40 – 0 – 300 – 200 – 100	$13,45^{ab}$	$126,47^{bc}$	$7,59^{ab}$	$9,60a^{b}$
T3: 0 – 40 – 1 – 300 – 200 – 100	$13,61^{ab}$	$138,66^{b}$	$8,55^{a}$	$11,86^{b}$
T4: 0 – 40 – 1 – 300 – 200 – 0	$13,92^{a}$	$107,51^{cd}$	$7,60^{ab}$	$8,17^{ab}$
T5: 6 – 40 – 1 – 300 – 200 – 100	$12,55^{ab}$	$167,07^{a}$	$8,31^{a}$	$13,89^{a}$
T6: 6 – 0 – 1 – 300 – 200 – 100	$11,67^{b}$	$139,31^{ab}$	$8,35^{a}$	$11,64^{ab}$

Means followed by the same letter in the same column are not significantly different at the 0.05 HSD level.

The lowest sugar production is obtained when sugarcanes are fertilized only by inorganic fertilizers (T1). However, when inorganic fertilizers are applied together with kettle ash, sugar production increased significantly by about 60% (T2 vs T1). Furthermore, when inorganic fertilizers are applied together with all soil ameliorants, compost – kettle ash – dolomite, the sugarcane productions increased significantly from 99% (T3 vs T1) to 133% (T5 vs T1). The data can explain that compost, kettle ash, and dolomite synergize with inorganic fertilizers to increase sugarcane productions.

The mineralization of compost and kettle ash may cause a soil acidity effect, but this effect was neutralized by dolomite. Compost and kettle ash, therefore, improve soil quality by improving soil air circulation and releasing minerals. The application of biochar like kettle ash increased cation exchange capacity and the availability of phosphorous and nitrogen (Gana, 2009). Compost used in this research contain nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O)each of 0,35%, 6,33% and 4,32%. Kettle ash contain nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O)each of 0,32%, 5,32% and 4,63%.

The application of compost as much as 6 t ha^{-1} produced the higher of sugar. This yield was the same to (Purwono, et al., 2011), which reports that the higher sugar yield can be obtained from using 5 t ha^{-1} of compost also state that the applications of compost continuously over three years can significantly increase sugar yield (Calcino, et al., 2009).

4 CONCLUSIONS

1. Soil ameliorants significantly improved growth components such as root length up to 45 m, plant height up to 2,89 m, stem diameter around 3,0 cm, and some tillers about 13 stems in one meter of row.
2. Soil ameliorants were improving not only the growth component but also the yield component of sugarcane. When all soil ameliorant, compost–kettle ash–dolomite, are applied together with inorganic fertilizers, urea–superphospates3 6–potassium chloride, sugar production increase up to 100%.

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