Collaboration of liquid bio-ameliorant and compost effect to crop yield and decreasing of inorganic fertilizer utilization for sustainable agriculture

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Abstract. Soil quality and plant productivity are main issue in agriculture production. The purpose of this research was to obtain sustainable crop management in effort to improve soil quality and increase maize production through collaboration of liquid bio-ameliorant and compost. Field experiment was carried out in two planting season with factorial experimental design replicated three times in 2m x 2m plots. Duncan multiple range test was used to analysis the effect of treatment on all parameters evaluated. The first planting season, treatments were arranged in three factors as: (1) planting space with two spaces, (2) three concentration of liquid bio-ameliorant, and (3) three level of urea fertilizer. The second planting season, treatments were arranged in two factors as: (1) liquid bio-ameliorant (LBA) with four concentrations and (2) compost with four levels. In the first season, result showed in soil quality parameters such as microbial density and soil chemical properties increased approximately 28%. The highest yield of 9.00 ton ha^{-1} was found in application 300 ml l^{-1} LBA + urea 240 kg ha^{-1}. In the second season, collaboration treatment of 250 ml l^{-1} LBA + 10 ton ha^{-1} compost had the highest yield by 10.47 ton ha^{-1}. This study confirmed that collaboration of liquid bio-ameliorant and compost could be used as fertilizer complement and reducing inorganic fertilizer utilization to sustain crop production and soil quality**.**

1. Introduction

Environmental plant management and implementation of appropriate production technology is the main frame in improvement and development of sustainable plant production. The adoption of better management practices (BMPs) can be practice to improve soil organic carbon (SOC) content, enhance soil quality, restore degraded ecosystems, increase biomass production, improve crop yield, and encourage investment in soil resources for soil restoration [1]. Intensive agricultural practices in conventional farming systems negatively impact the soil biological communities of agroecosystems due to the disturbance induced by chemical fertilizer, pest control measures or soil tillage [2]. Application of green manure and/or crop residues incorporation have been proposed as alternative cropping system in order to reduce SOC when farmyard manure is unavailable [2, 3]. Sugar mill wastes have been used as ameliorant for example, ash applications raise soil pH [4] whilst filter cake adds organic matter as well as raising pH [5]. Recently, combining of organic bio-ameliorant with chemical fertilizer could be alternate practice in optimizing crop production and maintain soil

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productivity. Benítez-Noyola [6] demonstrated that maize plants fertilized with 90 and 180 kg ha^{-1}N and inoculated with *Paenibacillus polymyxa* extracted from 20 to 28% more nitrogen and produced more grain than plants that were only chemically fertilized. The possibility of maintaining grain maize yields by replacing 87 kg ha^{-1} Urea (50%) of the complete N fertilizer dose (175 kg ha^{-1}) with 300 kg/ha of an organic compost elaborated with fruit and vegetable wastes and enriched with 147g N/kg N compost [7]

Agriculture by product as organic material is often found in agricultural production area which was in many cases it become waste. The other organic material source comes from liquid (sludged) waste of biogas product. These materials can be used to produce liquid bio-ameliorant through anaerobic fermentation process [8]. The basic process is activation of biological community to mineralized organic material which it mentioned as biological processes. It is crucial for the maintenance of soil fertility due to their role in the mineralization of organic matter, enhance plant nutrient uptake, and sustainability of crop production [9]. This is consideration on how it is necessary to study the effect of collaboration of liquid bio-ameliorant and compost to reduce nitrogen utilization and increasing maize production. Better knowledge and considerable technology of maize cultivation management practices through the combination application of liquid bio-ameliorant and compost for achieving sustainable agriculture is the main challenge and purpose of this study.

2. Materials and methods

Field experiment was carried out in Teaching Farm, Faculty of Agriculture, Hasanuddin University. Two planting season of maize was set up with factorial experimental design replicated three times in 2m x 2m field plots. The first planting season, treatments were arranged in three factors as: (1) planting space with two type spaces (P_1 = 75cm x 25cm and P_2 = 50cm x 20cm); (2) liquid bio-ameliorant (LBA) with three concentrations (B_0=0; B_1=100; and B_2=300 ml l^{-1}); and (3) urea with three levels (N_0=0; N_1=240 and N_2=300 kg ha^{-1}). Treatment in the second season were arranged in two factors as: (1) LBA with four concentrations: (B_0=0; B_1=150; B_2=250 and B_2=350 ml l^{-1}); and (2) compost with four levels: (K_0=0; K_1=2; and K_2=5; and K3 =10 ton ha^{-1}). In this season, planting space of 75 x 25 cm was practiced**.**

Liquid bio-ameliorant was starting applied two weeks after planting and it continued within every two weeks interval during vegetative growth period. Nitrogen fertilizer treatment was applied in split three times: 40% in 7 Days After Planting (DAP), 30% in 30 DAP, and 30% 50 DAP. Furthermore, all plots were supplemented additionally with 150 kg ha^{-1} super phosphate (SP36) and 100 kg ha^{-1} potassium chloride (KCl). Preparation of liquid bio-ameliorant was done by mixing all materials organic containing sludge of biogas, lake organic material sediment, plant by-product. Liquid bio-ameliorant was ready for use after approximately four (4) weeks incubation. Soil sample for soil chemical properties analysis was collected as composite sample.

Liquid bio-ameliorant, soil and plant analysis was conducted at the Laboratory of Soil Chemistry and Fertility, Department of Soil Science, Faculty of Agriculture, Hasanuddin University, Makassar. Statistically analysis of significant difference the experiment using ANOVA and the effect of different treatment was evaluated using Duncan's multiple range test. All statistical analysis was performed using IBM-SPSS ver. 20 computer package.

3. Result and discussion

3.1. Soil, liquid bio-ameliorant and compost properties

Soil type in the field experiment was Typic Hapludalfs [10] which means the soil has moderate nutrient content with high base saturation (>35%), high sum of basic cations and has an argilic horizon (clay accumulation subsurface horizon). Selected of soil and liquid bio-ameliorant properties was summarized in Table 1. Maize cultivation was highly depend on the soil fertility and environmental conditions. In case of soil with low nutrient content, especially nitrogen can decrease maize production significantly. However, application of inorganic fertilizer for long term tend to decreased soil quality and it caused direct effect to the environment and plant production. In this case a combined method to

maintain sustainability production could be achieved by supplementing crop production environment using organic material such as liquid bio-ameliorant.

Result of soil and organic matter analysis showed enrichment nutrient more than 50% obtained from LBA and compost. Soil fertility is also increased from additional microbe density of 11x104 cfu as biological component. Increasing of chemical and biological properties have possibility to soil physical properties and its effect will increase quality of plant environmental production.

Table 1. Selected properties of soil, liquid bio-ameliorant, and compost

Properties	Soil	LBA
Chemical properties		
CEC (me/100g)	18.34	-
pH (H_20)	6.12	6.23
P_20_5 (ppm P)	12.76	10.01
N-total (%)	0.06	0.49
C-organic (%)	1.94	0.98
K (cmol(+)kg^{-1})	0.22	0.82
Ca (cmol(+)kg^{-1})	6.36	31.71
Mg (cmol(+)kg^{-1})	2.67	2.78
Na (cmol(+)kg^{-1})	0.33	7.99
Soil fractions		
Sand (%)	20	-
Silt (%)	28	-
Clay (%)	52	-
Microbial density (cfu)		11 x 10^4

3.2. Soil Quality Improvement

Maintaining sustainability or improving soil quality could be achieved by application combination method between chemical fertilizer and organic matter or combining organic material in different type such as liquid bio-ameliorant and compost. Table 2 showed clear result that liquid bio-ameliorant could be applied to improve soil quality.

Table 2. Soil quality improvement on collaboration of liquid bio-ameliorant and nitrogen treatment

Treatments	Soil Chemical Properties								
	C	N	P2O5	K	Ca	Mg	Na	CEC	BS
	%	%	ppm	---------- cmol(+) / kg ----------					%
N0B0	1.94	0.06	10.99	0.22	6.36	2.67	0.33	18.34	52
N0B1	1.75	0.34	36.87	0.25	8.38	4.87	0.41	22.33	62
N0B2	2.49	0.36	37.82	0.36	7.90	3.50	0.38	24.33	50
N1B0	2.14	0.31	18.48	0.17	6.83	4.63	0.33	28.51	42
N1B1	2.59	0.08	34.99	0.25	7.78	3.03	0.42	22.13	52
N1B2	2.59	0.28	35.74	0.22	7.48	2.79	0.61	24.13	46
N2B0	2.71	0.22	10.00	0.22	6.83	2.85	0.35	22.53	46
N2B1	2.24	0.24	34.99	0.24	8.49	0.42	0.52	21.34	45
N2B2	2.70	0.21	34.04	0.33	8.08	1.60	0.41	21.14	49

Comparison on single treatment of LBA and nitrogen showed LBA give better result than nitrogen. Evaluation in all nutrient content except in carbon content was found higher value in LBA than nitrogen with increasing of LBA value in average of 10.82%.

With regards to combination concentration effect was analyzed treatment of 300 ml l^{-1} LBA and 240 kg ha^{-1} nitrogen have highest value for macro nutrient (N, P and K). Some combination treatment such as 300 ml l^{-1} LBA and 300 kg ha^{-1} nitrogen have high value in carbon organic, potassium and calcium. These two facts were put an important that high concentration of liquid bio-ameliorant and low level nitrogen had highest increase of nutrient content compare to the other treatment. Improvement soil quality could be related to the increasing of mineralization and transformation of organic material with activation of microbial activity.

3.3 Effect of Collaboration Treatment on Plant Performance

Plant density and fertilizer management are two components in cultivation system have significant effect to increase yield. Plant height and biomass were plant performances with clear response affected by planting space, nitrogen, liquid bio-ameliorant and compost application (table 3 and 4). In the first season, plant height showed significant response in the treatment of nitrogen fertilizer, but liquid bio-ameliorant, and planting space have various difference effect on this combination treatment (table 3).

Table 3. Effect of Collaboration Treatment on Plant Height (cm)

First season	Average	Second season	Average
$P_1B_0N_0$	134.37^{a}	**B0K0**	146.71^{a}
$P_1B_1N_0$	137.77^{a}	**B0K1**	179.21^{b}
$P_1B_2N_0$	143.50^{a}	**B1K0**	183.88^{b}
$P_2B_2N_0$	150.55^{a}	**B0K2**	194.63^{b}
$P_2B_0N_0$	153.19^{a}	**B1K1**	207.25^{b}
$P_2B_1N_0$	157.65^{ab}	**B3K0**	216.50^{b}
$P_1B_2N_1$	167.90^{b}	**B3K1**	221.21^{bc}
$P_1B_0N_2$	171.40^{b}	**B2K0**	229.83^{c}
$P_1B_0N_1$	176.03^{b}	**B2K1**	230.46^{c}
$P_1B_1N_2$	177.33^{b}	**B1K2**	231.04^{c}
$P_2B_0N_2$	177.90^{b}	**B3K2**	233.25^{c}
$P_2B_2N_1$	178.86^{bc}	**B0K3**	233.63^{c}
$P_2B_1N_2$	183.00^{c}	**B2K3**	238.25^{cd}
$P_2B_2N_2$	183.55^{c}	**B2K2**	244.71^{d}
$P_1B_2N_2$	183.57^{c}	**B3K3**	263.00^{d}
$P_2B_0N_1$	184.64^{c}	**B1K3**	268.84^{d}
$P_2B_1N_1$	185.60^{c}		
$P_1B_1N_1$	198.07^{c}		

Data followed by different letters indicate significant differences at $P < 0.05$

Plant height showed almost combination treatments between liquid bio-ameliorant and nitrogen has highest value ranged from 177.33cm to 198.07cm. Treatment without nitrogen showed the lowest value ranged from 134.37cm to 157.65cm. The overall evaluation on this parameter was found that combine application of planting space of 75cm x 25cm, 100 ml l^{-1} LBA, and 240 kg ha^{-1} urea had the highest value, but no significant effect to planting space of 50cmx20cm, 300 ml l^{-1} LBA, and 240 kg ha^{-1} urea or planting space of 50cmx20cm, 100 ml l^{-1} LBA, and 300 kg ha^{-1} urea. Result for plant biomass parameter was follow tendency result of plant height. The highest result was shown by combination treatment of planting space of 75cmx25cm, 100 ml l^{-1} LBA, and 240 kg ha^{-1} urea, but it is not significant different result to planting space of 75cmx25cm, 100 ml l^{-1} LBA, and 300 kg ha^{-1} urea. In the second season, liquid bio-ameliorant and compost treatment was observed higher value in combination than single treatment (table 3 and 4). All treatment was significant effect compare to control on plant height. Generally, combination treatment between liquid bio-ameliorant and compost showed highest value in all treatment. Plant height value in this combination ranged from 207.25cm to 268.84cm. The interesting result was found within concentration of liquid bio-ameliorant and

compost. The highest value of plant height was 268.84cm for application 150 ml l^{-1} LBA with 10 ton ha^{-1} compost, but it was not significant to the treatment of 250 or 350 ml l^{-1} LBA with 5 or 10 ton ha^{-1} compost. In plant biomass result was found also that all treatment significant effect to plant biomass. Combination treatment between liquid bio-ameliorant of different concentration with 10 ton ha^{-1} compost showed high value compare to the other combination or single treatment.

Table 4. Effect of Collaboration Treatment on Plant Biomass Weight (g)

First season	Average	Second season	Average
$P_2B_0N_2$	51.50^{a}	**B0K0**	68.33^{a}
$P_1B_0N_0$	53.57^{ab}	**B1K0**	90.00^{b}
$P_1B_1N_0$	54.00^{b}	**B0K1**	100.67^{b}
$P_2B_0N_0$	56.83^{b}	**B2K0**	124.00^{b}
$P_2B_2N_0$	57.57^{b}	**B1K1**	139.00^{b}
$P_2B_1N_0$	61.53^{b}	**B3K1**	140.00^{b}
$P_2B_1N_1$	67.27^{b}	**B3K0**	145.67^{bc}
$P_2B_1N_2$	75.47^{b}	**B2K1**	145.67^{bc}
$P_1B_2N_2$	80.00^{b}	**B0K2**	150.67^{c}
$P_1B_2N_0$	82.37^{b}	**B1K2**	152.33^{c}
$P_2B_0N_1$	85.60^{bc}	**B2K2**	156.67^{c}
$P_1B_0N_1$	96.37^{c}	**B0K3**	181.67^{d}
$P_2B_2N_1$	96.97^{c}	**B3K2**	182.33^{d}
$P_1B_2N_1$	98.77^{c}	**B1K3**	184.00^{d}
$P_2B_2N_2$	109.43^{c}	**B2K3**	206.67^{d}
$P_1B_1N_2$	110.83^{c}	**B3K3**	206.67^{d}
$P_1B_0N_2$	119.27^{c}		
$P_1B_1N_1$	124.00^{c}		

Data followed by different letters indicate significant differences at $P < 0.05$

3.4. Plant Production

Plant production is illustrates of the working of interactions of various factors which are determine all production process including soil, fertilizers, and the environmental production. Total yield in this experiment was shown in table 5.

Table 5. Maize production for two planting seasons

First season	Yield (ton ha^{-1})	Second season	Yield (ton ha^{-1})
$P_1B_0N_0$	3.00	**BK0**	4.31
$P_2B_0N_1$	3.12	**BK1**	6.40
$P_1B_1N_2$	5.32	**BK2**	8.02
$P_2B_2N_1$	9.00	**BK3**	10.47

The collaboration treatment effect between liquid bio-ameliorant and compost was shown clear effect on production. Combination treatment of 250 ml l^{-1} LBA and 10 ton ha^{-1} compost showed the highest value of 10.47 ton ha^{-1} compare to the other combination. The result was found also that LBA improving environmental production as reducing nitrogen fertilizer, improving soil quality and affect

plan production, directly. The result could be used to confirmed the usefulness of liquid bio–ameliorant as material in improving maize production.

4. Conclusion

Soil quality improvement and increasing maize production was affected by environmental management and soil properties. Plant performance had high results under combination treatments between low liquid bioameliorant concentration and high nitrogen fertilizer application. The combination treatment effect between liquid bio-ameliorant with nitrogen or liquid bio-ameliorant with compost can increase production until more than 10 ton ha^{-1} compare to control with total production around 3 ton ha^{-1}. This result confirmed that liquid bio-ameliorant combining with compost could be used as fertilizer substitution or complement to reduce chemical fertilizer utilization. For the future, liquid bioameliorant has potential as bio material in improving maize production sustainability.

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