

Effects of Organic Fertilizer on Soil Characters, Maize Growth and Grain Yield

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Abstract: Maize demand in Bali was supplied from other provinces because productivity was low at around 3,0 tons ha⁻¹. This assessment have been conducted in Sanggalangit Village, Gerokgak Districts, Buleleng, Bali from January to March 2010. The research was designed with factorial randomized block design, three replications. Two treatments were tested namely cow manure dosage: 0 tha⁻¹, 5 tha⁻¹, 10 tha⁻¹ and 15 tha⁻¹; bio urine dosages: 0 liter ha⁻¹, 25.000 liters ha⁻¹, 50.000 liters ha⁻¹ and 75.000 liters ha⁻¹, so there were 16 treatment combinations. Increasing dosage of cow manure reduced the bulk density of from 1.23 to 1.16, increased soil moisture content from 31.11% to 35.17% and increased total soil pore space from 53.64% to 56.23%, increased C-organic from 0.27% to 1.67%. Interaction between cow manure and bio urine increased N-total up to 36.22%, with linear equation $Y=2.049+7.16\times 10^{-2}Manure+1,26\times 10^{-5}U$ ($R^2=0.862^{**}$) to dry grain yield so that optimum dosage has not been obtained.

Keywords: organic fertilizer, soil character, growth and yield, maize

1. INTRODUCTION

In Indonesia, maize is the second most important food commodity after rice. Suastika et al.¹ stated that the demand for maize from year to year continues to increase, especially for food. Data from 1995 showed that 63% of maize needs were used for food, 30.5% for animal feed and the rest was for industrial needs. Muhammad and Akuba² stated that Indonesia's maize production was estimated to increase by 4% per year in 2005-2010. The use of maize for feed increased 4.9%, for food increased 2%, while the use of maize for industry increased by 3%. Increased maize production was not expected to offset consumption demand until 2010. Supply in 2010 was estimated at 9.9 million tons while demand reaches 15.9 million tons. Potential demand for maize in 2005 in Bali was 209,093 tons³, while maize production in Bali was 88,692 tons, therefore, Bali still lacked of maize by approximately 120,401 tons⁴.

Maize productivity in Bali from 2003 to 2007 was still very low, ranging from 2.65 – 3.00 tons ha⁻¹, by which the Buleleng Regency had the highest planting area compared to other Regencies⁴. Agung et al.⁵ added to the maize farming in Patas Village, Gerokgak Districts, Buleleng Regency, farmers generally use local varieties that have adapted well to local conditions but their production was generally low. The level of production produced was approximately 3.0 t ha⁻¹ dry shelled. The planting area of maize in Gerokgak Districts in 2008 was 7,207 hectares with a production of 23,055 tons of dry grain, so that the productivity was 3.20 tons ha⁻¹. Low land fertility was one of the causes of low maize production¹. The production constraints were partly due to the poor soil physical properties and soil stability in macro and micro elements, thereby reducing land productivity⁷.

Nitrogen manure was one source of soil organic matter which is very useful in improving physical, chemical and biological soil properties. Manure can increase pH, levels of C-organic and increase the availability of nitrogen, phosphorus, potassium and micro-elements for plants^{8,9}. Kuntiyastuti and Rahmiana¹⁰ stated that the use of organic fertilizer in an effort to increase land productivity requires quite high amounts of fertilizer, so that it becomes a limiting factor in large-scale application. To overcome this high amounts of manure required, the use of bio urine may be one choice in large-scale microorganisms).

Bio urine is produced by fermenting animal urine¹¹. To process the waste from cow manure (urine) into more useful and potentially useful products, a fermentation technology package is needed by involving the role of bacteria (microorganisms) to convert or transform chemical compounds to organic substrates so that they can be implemented directly as nutrients in agricultural crops¹². Utilization of urine or bio urine for fertilizing plants was still very rarely applied. Adijaya¹³ obtained the utilization of 7,500 liters ha⁻¹ (1 ha⁻¹) of cow urine combined with 5.0 t ha⁻¹ cow manure was able to increase the yield of shallots by 60.77%, while the application of cow's urine 15,000 l ha⁻¹ increased yield by 31.72% compared with no fertilization which resulted in a tuber of 6.45 t ha⁻¹.

Information about the results of cow manure and bio urine research was still very limited, therefore, research on this aspect needs to be done on maize plants which was one of the most widely cultivated plants in dry land.

2. MATERIALS AND METHODS

This research was a field trial, carried out in the dry land of Sanggalangit Village, Gerokgak Districts, Buleleng Regency, Bali Province, Indonesia with rainfall of 1,200 mm - 1,400 mm year⁻¹ and altitude + 50 m above sea level (ASL). The research was conducted from January 3 to March 22, 2010. The results of the soil analysis of the test site showed low N-total and C-organic soil, i.e 0.110% and 1.03%. The research was arranged in factorial randomized block design (RBD) with 3 replications. Two treatments tested, namely dosage of animal manure and bio-urine dosage of cow, each consisted of 4 levels, resulted in 16 total combination treatments. The dosage treatments of tested cow manure dosage consisted of 4 levels, namely: M₀ = Cow manure 0 t ha⁻¹ (without cow manure), M₁ = Cow manure 5 t ha⁻¹, M₂ = Cow manure 10 t ha⁻¹, and M₃ = Cow manure 15 t ha⁻¹. Treatment of cow's bio-urine dosage consisted of 4 levels, namely: U₀ = Bio-urine of cow 0 l ha⁻¹, U₁ = Bio-urine of cow 25,000 l ha⁻¹, U₂ = Bio-urine of cow 50,000 l ha⁻¹, and U₃ = Bio-urine of cow 75,000 l ha⁻¹.

Cow manure was analyzed at the Department of Soil Laboratory, Faculty of Agriculture, Udayana University, 2007, while cow urine urine was analyzed at the Bogor Soil Research Institute, 2007. Data analysis of cow manure and bio-urine are presented at Table 1.

Table 1. Analysis of cow manure and bio-urine

Type of Analysis	Cow Manure	Cow Bio-Urine
pH	7.90	8.50
C-organik (%)	23.75	0.49
N total (%)	1.78	0.18
P available (ppm)	79.64	76.00
K available (ppm)	9616.68	5974.00
Ca (ppm)		24.00
Mg (ppm)		274.0

The maize seeds used in this research was Seraya Local varieties. Soil processing was carried out 2 times. In the second tillage, plots of 3.60 m x 4.00 m were formed. The distance between treatment plots was 0.5 m and the distance between replications was 1.0 m. Planting was done by using three to three grain per hole with a spacing of 60 cm x 40 cm, leaving 2 plants per planting hole.

The treatment of cow manure that has been fermented (ripe) was given one week before planting according to treatment. Fertilization with bio-urine of cow was given 4 times each ¼ dose, namely at the age of 14, 28, 42 and 56 days after planting by splashing near the base of the plant according to the treatment dose. The volume of bio-urine of cow that were given were respectively 0 l of clump⁻¹ (bio-urine of cow 0 l ha⁻¹), 0.15 l of clump⁻¹ (bio urine of 25,000 l ha⁻¹), 0.30 l of clump⁻¹ (bio-urine of 50,000 l ha⁻¹) and 0.45 l of clump⁻¹ (bio urine of 75,000 l ha⁻¹) for each treatment. Giving cow bio urine with a concentration of 20% (1 liter of urine: 4 liters of water). Weeding was done at the age of plants 21 and 42 days after planting. Harvesting was done at the age of 80 days after the cob has been dried, 75% of the leaves of the plant have yellowed and dried, the grain were dense, shiny and if pressed feels hard. Observations were made on the physical and chemical properties of the soil as well as the growth and yield of maize.

2.1. Soil Physical Properties

Soil physical properties observed were weight of soil volume, soil moisture content and total pore space, with the following mechanism:

1. Bulk volume weight (g cm⁻³)

Observation of plant age 42 days after planting and at harvest timewas done by taking soil samples in the field using a sample ring at a depth of 0 cm - 10 cm. Weight of soil volume was calculated by the formula:

Weight of oven dry soil (g)

$$\text{Soil volume weight} = \frac{\text{Weight of oven dry soil (g)}}{\text{Soil volume (cm}^3\text{)}} \quad (1)$$

2. Soil water content (%)

Soil water observations were carried out using gravimetric method¹⁴, namely at plant age 42 days after planting and at harvest time. Soil water content was calculated using the formula:

Wet soil weight (g) - Oven dry soil weight (g)

$$\text{Soil water content (\%)} = \frac{\text{Wet soil weight (g) - Oven dry soil weight (g)}}{\text{Oven dry soil weight (g)}} \times 100\% \quad (2)$$

Weight of oven dry soil (g)

3. Total pore space (%)

Measurements were calculated based on the results of determining the soil volume weight (bulk density) and soil particle density (2.65 g cm⁻³)¹⁵. The measurement of pore space was carried out at 42 days after planting and at harvest timewith the equation:

$$f = (1.0 - b / p) \times 100\% \quad (3)$$

Where: f = total pore space (%), b = soil volume weight (g cm⁻³), p = soil particle density by assumption of 2.65 g cm⁻³.

2.2. Soil Chemical Properties

Observations on the soil chemical properties were carried out on total N, C-organic and soil pH at harvest. Determination of total N and C-organic soil was done by taking soil samples from each treatment plot of 500 g and then dried, fine sifted and analyzed in a laboratory. The method used for the determination of the N-total was the Kjeldahl method while the C-organic was the Walkey and Black method.

2.3. Maize Growth and Yield

The agronomic parameters observed were growth components (plant height, number of leaves plant⁻¹, leaf area index (LAI), and oven dry weight with plant⁻¹ and ha⁻¹sequences) and yield components (oven dry grain weight and grain weight 12% plant⁻¹) and ha⁻¹ production (oven-dried grain and 12% ha⁻¹grainmoisture content) and harvest index. Data were analyzed for variance, if the interaction between dosage of manure and bio urine significantly affected continued with the Duncan test level of 5%, if the single treatment with significant effect was followed by LSD test level of 5%¹⁶.

3. RESULTS AND DISCUSSION

3.1. Soil Physical Properties

Application of cow manure alone has a significant effect on the physical properties of the soil of the trial location such as reducing the weight of the soil volume (bulk density), increasing the water content and the total pore space of the soil at harvest. Bulk density significantly decreased with the application of 15 t ha⁻¹ cow manure, from 1.23 g cm⁻³ to 1.16 g cm⁻³, the water content increased from 31.11% to 35.17% and the total soil pore space increased from 53.64% to 56.23% (Table 2).

The results of this study were in line with the results of the Suratmini¹⁷ study which stated that the application of 15 tons of ha⁻¹ fertilizer sometimes cow reduced the soil bulk density from 1.00 g cm⁻³ to 0.98 g cm⁻³, increasing the water content from 27.22% to 29, 11% and increase pore space 62.32% to 63.09%. Muku¹⁸informedthat applied 15 t ha⁻¹of cow manure fertilizer on onions reduced the soil bulk density from 0.14 g cm⁻³ to 0.12 cm⁻³ and increased soil moisture content from 15.87% to 17.52%. Aguset al.¹⁹ stated that soil bulk volume was one of the most commonly determined physical

properties of soil, because it was closely related to the ease of root penetration in the soil, drainage and soil aeration.

Table2. Effect of single dose of cow manure and bio urine on soil volume (bulk density), moisture content and total pore space of the soil at harvest

Treatments	Soil bulk density	Soil moisture content	Total soil pore space
	(g cm ⁻³)	(%)	(%)
Dosage of cow manure (t ha ⁻¹):			
0	1.23 a	31.11 c	53.64 d
5	1.19 b	34.06 b	55.10 c
10	1.18 c	35.08 ab	55.56 b
15	1.16 d	35.17 a	56.23 a
LSD 5%	0.02	1.03	0.25
Dosage of cow bio urine (l ha ⁻¹):			
0	1.19 a	33.67 a	55.01 a
25,000	1.19 a	34.17 a	55.19 a
50,000	1.19 a	33.79 a	55.14 a
75,000	1.19 a	33.80 a	55.19 a
LSD 5%	-	-	-

Note: Figures for the same treatment and column followed by the same letter were not significantly different at the 5% LSD test.

3.2. Soil Chemical Properties

Soil N-total content levels at harvest increased as a result of the interaction of manure with cow's bio-urine (Table 3). These results were in line with the results of the study by Syukur and Harsono²⁰, which obtained an increase in fertilizer manure up to a dose of 30 t ha⁻¹ significantly increased the total N-level from 376.67 ppm to 474.00 ppm and N-available soil from 10.65 ppm to 11.14 ppm.

Soil N-total content of the study site before treatment was low, that was 0.11%. Sirappa²¹ stated that the critical nitrogen limit for maize plants was 0.15%. If the nitrogen content in the soil was lower than the critical limit, the maize plant will be very responsive to the nitrogen fertilization. The higher levels of nitrogen in the soil cause the nitrogen available to plants will increase, so that plant growth will be increasingly encouraged. This was due to the function of nitrogen which gives the fastest effect on plant growth compared to other nutrients. Sutejo²² and Poerwowidodo²³ stated that nitrogen was needed to stimulate vegetative growth, to increase chlorophyll increasing the size of leaves and grain. Lack of nitrogen will reduce the amount of chlorophyll in the leaves, which causes the rate of photosynthesis to decrease so that the resulted photosynthate decreases.

Table3. Effects of interactions between dosage of manure and bio-urine of cow on total N-soil at harvest

Treatments	N-total (%)			
	Dosage of cow manure (t ha ⁻¹)			
	0	5	10	15
Dosage of bio urin (l ha ⁻¹)				
0	0.13c	0.16 ab	0.12 c	0.15 abc
25,000	0.12 c	0.13 bc	0.13bc	0.14bc
50,000	0.16 abc	0.14bc	0.14 abc	0.16 ab
75,000	0.14 abc	0.15abc	0.17 a	0.14 abc

Note: Figures for the same treatment and column followed by the same letter were not significantly different in the 5% LSD test.

C-organic soil at harvest increased due to the sole effect of cow manure and cow bio-urine treatment. Increasing dosage of cow manure to 15 t ha⁻¹ increased the soil C-organic content from 0.27% to 1.67% or an increased of 518.52%, while increasing the cow's bio-urine dose to 75,000 l ha⁻¹ increased the C- content soil organic matter from 0.75% to 1.18% or an increase of 57.33% (Table 4). Gratitude and Indah²⁴ who examined the application of 10 t ha⁻¹, 20 t ha⁻¹ and 40 t ha⁻¹ cow manure on ginger plants stated that C-organic soil after harvest increased by 12.55%, 20.55 %, and 36.51% compared without fertilization (1.59%). The C-organic content of the soil decreases if fertilization was not carried out with organic fertilizer. At no fertilization the C-organic value was lower than the soil analysis before treatment was carried out from 1.03% to 0.27% and 0.75% (Table 4). Syukur²⁵ and

Syukur and Harsono²⁰ stated that the content of C-organic indicates the content of organic matter in the soil where the content of C-organic was approximately 58% of the soil organic matter. Application of organic fertilizer was needed to maintain and increase the content of C-organic in the soil. The treatment of cow manure and bio urine did not affect the soil pH. The soil pH range of the test site was 6.82 - 6.87 due to the treatment of cow manure and bio urine (Table 4).

Table4. Effects of single dosage of cow manure and bio-urine on C-organic and soil pH at harvest

Treatments	C- organic (%)	pH
Dosage of cow manure (t ha⁻¹)		
0	0.27 d	6.87 a
5	0.76 c	6.85 a
10	1.26 b	6.82 a
15	1.67 a	6.79 a
LSD 5%	0.24	-
Dosage of bio urin (l ha⁻¹)		
0	0,75 c	6,86 a
25,000	0,90 bc	6,80 a
50,000	1,12 ab	6,85 a
75,000	1,18 a	6,82 a
LSD 5%	0,239	-

Note: Figures for the same treatment and column followed by the same letter were not significantly different in the 5% LSD test.

3.3. Maize Growth and Yield

The growth component of Serayalocal maize was also significantly affected by manure and bio-urine fertilizer which was marked by an increase in growth components such as plant height, number of leaves, leaf area index (LAI), fresh weight and oven dry weight of biomass (Table 5). The biomass oven dry weight ha⁻¹ increased by 37.11% in fertilizer of 15 t ha⁻¹ cow manure and increased by 22.97% in fertilizer of 75,000 l ha⁻¹ bio-urine. The increase in the value of the components of Local Serayamaize was due to the increased production of assimilates compared to without fertilization. The increase in LAI was caused by an increase in the number of leaves, as well as an increase in leaf area. The maximum LAI, which was 49 days after birth, increased from 2.52 to 2.87 due to the influence of a single factor of cow manure and 2.55 to 2.83 due to the influence of a single factor of bio-urine (Table 5).

Table5. Effect of single dose of cow manure and bio urine on plant height, number of leaves, LAI and biomass oven dryweight

Treatments	Plant height(cm)	Number of leaves	Leaf area index	Biomass oven dryweight	
				(g plant ⁻¹)	(t ha ⁻¹)
Dosage of cowmanure (t ha⁻¹)					
0	297.23 d	9.83 d	2.52 d	42.34 c	3.53 c
5	311.18 c	10.08 c	2.67 c	48.13 b	4.01 b
10	316.24 b	10.26 b	2.77 b	52.67 ab	4.39 ab
15	323.53 a	10.57 a	2.87 a	58.05 a	4.84 a
LSD 5%	4.81	0.11	0.05	5.48	0.46
Dosage of cow bio-urine (l ha⁻¹)					
0	299.39 d	9.78 d	2.55 d	44.63 c	3.70 c
25.000	310.39 c	10.13 c	2.68 c	48.41 bc	4.04 bc
50.000	316.68 b	10.35 b	2.77 b	53.80 ab	4.48 ab
75.000	321.76 a	10.48 a	2.83 a	54.63 a	4.55 a
LSD 5%	4.81	0.11	0.05	5.48	0.46

Note: Figures for the same treatment and column followed by the same letter were not significantly different in the 5% LSD test.

The increased assimilate production resulted in an increase in the harvest index of 121.39% in the combined treatment of cow manure with a dose of 15 t ha⁻¹ with bio urine at a dose of 75,000 l ha⁻¹ compared without fertilization (Table 6). Purnomo²⁶ states that if the maize leaf area index was 1.14-2.42, it means that the prediction of intercepted light was 79-89% so that it still increases the economic yield of the plant so that the harvest index was still increasing. Goldsworthy cit. Fwascher

and Palmer (1995 in Indradewa et.al.²⁷), that the optimum leaf area index for grain yields was between 2.5 and 5.0. If the leaf area index was greater than this value, the addition of dry matter produced was mainly buried in the stems.

The increase in the harvest index due to fertilizer manure and bio urine of cow was caused by the increasing economic results produced. Increasing dosage of cow manure and bio urine increase the weight of grain produced. It was indicated by dosage of manure up to 15 t ha⁻¹ and bio urine up to 75,000 l ha⁻¹ causing local maize plants as more and more was allocating assimilates to storage organs.

Table 5. Effect of interaction between dosage of manure and bio-urine of cow on the weight of the oven dry grain, grain weight at 12% moisture content and harvest index

No.	Treatments	Grain weight at oven dry		Grain weight at 12% moisture content		Harvest index
		plant ⁻¹ (g)	ha ⁻¹ (t)	plant ⁻¹ (g)	ha ⁻¹ (t)	(%)
1	Manure ₀ Urine ₀	19.65 k	1.64 k	21.52 j	1.79 j	22.58 j
2	Manure ₀ Urine ₁	30.32 j	2.52 j	33.14 i	2.76 i	31.06 i
3	Manure ₀ Urine ₂	33.27 hij	2.77 hij	36.36 ghi	3.03 hi	33.06 hi
4	Manure ₀ Urine ₃	35.59 fgh	2.97 fgh	39.10 efg	3.26 efgh	34.56 efgh
5	Manure ₁ Urine ₀	30.98 ij	2.58 ij	33.87 hi	2.82 i	31.52 i
6	Manure ₁ Urine ₁	34.68 ghi	2.89 ghi	38.01 fgh	3.17 gh	33.96 gh
7	Manure ₁ Urine ₂	37.32 defg	3.11 defg	41.24 def	3.44 defg	35.69 defg
8	Manure ₁ Urine ₃	39.68 cde	3.31 cde	43.43 cde	3.62 cde	37.08 cde
9	Manure ₂ Urine ₀	35.08 fgh	2.92 fgh	38.44 fg	3.20 fgh	34.23 fgh
10	Manure ₂ Urine ₁	35.93 efgh	2.99 efgh	39.61 efg	3.30 efgh	34.80 efgh
11	Manure ₂ Urine ₂	39.05 def	3.25 def	42.92 de	3.57 def	36.70 def
12	Manure ₂ Urine ₃	43.19 bc	3.60 bc	47.41 bc	3.95 bc	39.07 bc
13	Manure ₃ Urine ₀	37.36 defg	3.11 defg	40.81 defg	3.40 defgh	35.69 defg
14	Manure ₃ Urine ₁	40.23 cd	3.35 cd	44.15 cd	3.68 cd	37.41 cd
15	Manure ₃ Urine ₂	44.19 b	3.68 b	48.73 b	4.06 b	39.61 b
16	Manure ₃ Urine ₃	50.78 a	4.23 a	55.76 a	4.65 a	42.99 a

Note: Figures for the same treatment and column followed by the same letter were not significantly different in the 5% Duncan test.

The increased of economic results can be seen from the increased of grain weight of plant⁻¹ and grain weight ha⁻¹. Increasing dosage of cow manure to 15 t ha⁻¹ and cow urine 12% water content) significantly increased grain weight of plant⁻¹ and grain weight ha⁻¹ (Table 6). The results of the regression analysis conducted on the oven dry weight ha⁻¹ obtained a linear equation with the equation $Y = 2.049 + 7.16 \times 10^{-2} \text{Manure} + 1.26 \times 10^{-5} \text{U}$ ($R^2 = 0.862^{**}$), while the relationship between dosage of cow manure and cow urine with grain weight ha⁻¹ at 12% moisture content with the equation $Y = 2,242 + 7.9 \times 10^{-2} \text{Manure} + 1.39 \times 10^{-5} \text{U}$ ($R^2 = 0.862^{**}$).

4. CONCLUSION

The single effect of cow manure improved soil physical properties by reducing bulk density, increasing water content and total pore space. Increasing the dosage of manure to 15 t ha⁻¹ reduced the bulk density at harvest from 1.23 to 1.16, increased soil water content from 31.11% to 35.17% and increased total soil pore space from 53.64% to 56.23%. Increasing dosage of cow manure and bio urine improved soil chemical properties. N-total soil at harvest increased due to the interaction of sometimes fertilizer and cow bio-urine 0,17% in the combination treatment of cow manure dosage of 10 t ha⁻¹ with cow bio-urine of 50,000 l ha⁻¹ compared without fertilization (0.13%). C-organic soil at harvest increased due to the sole influence of cow manure and bio-urine. Increasing dosage of cow manure to 15 t ha⁻¹ and cow urine urine to 75,000 l ha⁻¹ increased the C-organic soil at harvest from 0.27% to 1.67% and from 0.75% to 1.18%, respectively. Increasing the dosage of manure to 15 t ha⁻¹ and cow's bio-urine to 15 l ha⁻¹, still increased the growth and yield of Seraya local maize. The relationship between dosage of cow manure and bio-urine of cow with the oven dry weight ha⁻¹ and grain weight ha⁻¹ at 12% water content was linear with the equation $Y = 2.049 + 7.16 \times 10^{-2} \text{Manure} + 1.26 \times 10^{-5} \text{U}$ ($R^2 = 0.862^{**}$) and $Y = 2.224 + 7.9 \times 10^{-2} \text{Manure} + 1.39 \times 10^{-5} \text{U}$ ($R^2 = 0.862^{**}$).

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