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Research Article

Effectiveness of organic wastes and forages to increase soil fertility status and crop yield in dry lands

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Abstract: The main purpose of this study was to elucidate the effects of application of organic wastes and rotation of cropping system on soil fertility status and yields of dry field rice, maize, soybean, groundnut and mungbean in order to overcome soil degradation problems in dry land areas. Six cropping rotation systems (dry field rice-soybean-fallow, dry field rice-groundnut-fallow, dry field rice-mungbean-fallow, maize-soybean-fallow, maize-groundnut-fallow, and maize-mungbean-fallow), and six organic fertilizer rates (0, 5, 10, 15, 20 t/ha, and 25 t/ha) were arranged in a randomized block design with two replicates. The results showed that maize-groundnut-fallow and dry filed rice-groundnut-fallow cropping systems with application of 25 t/ha organic fertilizer were able to increase soil fertility status. At the two cropping systems, status of N-total, P-total, K-total, C-total, CEC, and soil pH were better than other treatments. Soil physical fertility status on maize-groundnut-fallow and dry filed rice-groundnut-fallow cropping systems with application of 25 t/ha organic fertilizer was better than other treatments. Implication of improvement of soil physic characteristic because of this treatment was capable of raising irrigation efficiency about 0.98. Soil biological fertility at the same treatments was also better than other treatments. The average of soil worms was 2.44 per m^2 soil. The amount of bacteria was 3.284 x 10^6 per gram soil. The amount of colony was 545.78 and the average of colony forming holozone was 19.66. Application of 20-25 t/ha organic fertilizer yielded higher crop yields than application of 0, 5, 10, an 15 t/ha organic fertilizer. Maize-groundnut-fallow cropping system and 25 t/ha application of organic fertilizer resulted in the highest propriety index, with value BC-ratio 2.54, $BEP_{production}$ 61760, and BEP_{value} 982.

***Keywords**: organic fertilizers, soil fertility status, crop yield, dry land*

Introduction

The demand for increasing maximal production in dry land has forced farmers to use synthetic fertilizers and pesticides beyond its recommendation and imbalance. Imbalance fertilizers can cause leaching of soil nutrients and trigger mineralization process of soil organic matters. In fact, this condition can faster process of soil pauperization on several regions in dry land in Lombok Island. The main cause of soil degradation is lost of soil tillage layer due to soil erosion about 4.6 – 14.43 t/ha/year (Ngawit et al., 2007). The same situation also occurs in several regions in Indonesia around 6-9 t/ha/year, while in USA is only about 0.7 t/ha/year (Indayati dan Subadiyasa, 2003; Simarmata et al., 2003). High level of erosion causes great lost of soil nutrients that in turn decreases rate of soil productivity. In addition, efforts to increase crop yield through application of artificial fertilizers, pesticide, and other compounds give negative impacts to environment and food products due to toxic compounds. These conditions can produce disaster rather than sustainable agriculture. Ngawit et al. (2007) indicated that there was a phenomenon of high land degradation in three types of dry land in Lombok island. This was shown by low productivity of the existing farming systems commonly practiced in the area. This occurred because of unfavourable conditions for crop production, i.e. unequal distribution of rainfall and eratical (3-4 wet months/year), lithography and topography, low of soil fertility status, population of soil cover crops, and low of fauna and soil microbes. To overcome this problem, Ngawit et al. (2008) developed structure plan model of integrated ecological farming system based on classification of agroecosystem appropriateness in three types of dry land in Lombok Island. The model has been proved to be able to generate soil fertility status and land productivity better than local farmer models. However, the model needs to be further developed by considering cheap sources of organic fertilizers.

Farming productivity decreases along with the decrease of soil organic matter content because applied farming systems cannot maintain balance between input and output in the soil (Ngawit et al., 2008). In addition, weed infestation is another major problem that is hard to deal with. Generally, control of weeds is conducted using mechanical and chemical methods i.e. herbicides that affects sustainability of ecological system. The use of weeds as livestock fodders is still restricted to certain weeds on rainy season or in the present of food crops. While in dry season farmers often find difficulties to get their livestock fodders, This makes farmers sale their cows before reaching certain weight. Thus, there is a significant decrease of animal population during dry season. As a result, this will lead to the reduction of organic fertilizers required for developing integrated ecological farming systems.

One of appropriate action to overcome this problem is by making optimal crop and livestock animals relation trough increase of livestock animals population consistently, especially *Ruminansia*. This will implicate on availability of basic substances of organic fertilizer stable during growing season either on quantity and quality or on continuity. Therefore, management of livestock waste, plants waste, and other forages as a basic substances of organic fertilizer using effective technology is urgent and the right choice.

In relation to that, it has been produced high quality of organic fertilizer through stages of research process i.e. the use of livestock waste and other agriculture waste. The first step is composting. All materials are mixed and embedded in soil hole with 1x1x1 m^3 in depth. This treatment are made three series and are mixed and added lime every week. After compost is formed, compost is again decomposed with EM-4 and *Trichoderma* spp. pure isolate as a decomposer for 4-6 weeks. This decomposition technique is able to enhance compost quality become organic fertilizer faster with indication decrease of C content and C/N-ratio of compost for about three weeks. This is also accompanied by increase of N, P, and K contents. Increase of N content of fertilizer during decomposition process up to 12 weeks reaching 0.89%, P content 1.32%, and K content 1.21% (Ernawati et al., 2013).

Use of livestock waste and other agriculture waste as fertilizer is still limited in fresh form and is given directly without effort to process. For example, in raise cows especially Bali cows, small breeders are used collective cage system. Livestock waste, dung and leftovers fodder are ignored and piled up around cage continuously without application of good management. As a result, dung and other cage waste become uncontrollable especially on rainy season so that those potential basic substances of organic fertilizer is washed away by rain flow (Asih, 2004).

Thus, effort to process livestock waste and other agriculture waste is important in order to guaranty availability enough basic substances of organic fertilizer both in quantity and in quality with stable continuity. Consequently, it is needed to harvest and to process livestock waste, agriculture waste, and other forages with application of effective technology in dry land. Nowadays, it is plentiful of livestock waste, agriculture waste, and other forages neglected because of no profit design for organic fertilizer (Ngawit, 2008).

This study was aimed to elucidate the effects of application of organic wastes and rotation of cropping system on soil fertility status and yields of dry field rice, maize, soybean, groundnut and mungbean in order to overcome soil degradation problems in dry land areas

Materials and Methods

There were two factors studied in this experiment, i.e. rotation plant design (t) and application of organic fertilizer (p). The rotation plant design factor consisted of six levels (t1= dry field rice-soybean-fallow, t2= dry field rice-groundnut-fallow, t3= dry field rice-mungbean-fallow, t4= maize-soybean-fallow, t5= maize-groundnut-fallow, and t6= maize-mungbean-fallow). The application of organic fertilizer factor (p) also consisted of six levels (p1= 0 t/ha, p2= 5 t/ha, p3= 10 t/ha, p4= 15 t/ha, p5= 20 t/ha, and p6= 25 t/ha). Thirty six treatments were arranged in a completely randomized block design with two replicates.

Experiment was conducted in location of integrated ecological farming system in Mumbul Sari village, sub district of Bayan, regency of North Lombok, for about nine months. The plot size was 20 m^2 (4m x 5m). The distance between plots was 1m and between block was 1.5m. Soil was plowed by minimum tillage by at dry condition. Planting was made according to treatments of rotation plant design with the first plant was dry field rice and maize. After first season harvesting, the plots were then used for growing soybean, groundnut, and mungbean in the second planting season. Planting distance of dry field rice, soybean, groundnut, and mungbean was 30x20 cm, while that of maize was 30x50 cm. Organic fertilizers were applied after soil tillage. In this experiment, synthetic fertilizers were not applied starting from the first growing season until the second growing season. After harvesting After harvesting the first and second growing season plants, in-situ plant residues were returned into soil.

Response variables observed in this study were soil fertility status and plants actual yield. Soil fertility status was observed before soil tillage and after harvesting crops of the second growing season. Those response variables were soil physical characteristic (volume weight, total of pores and pF curve, water content, texture, permeability, soil aggregate, and plasticity index), soil chemical characteristic (C-organic, N-total, exchangeable K, available P, C/N ratio, and pH), soil biological characteristics (population and activity of soil microbes that can triggered health/soil fertility (biofertilizer) and population and activity of soil micro and macro pores.

Biofertilizer microbes measured in the soil were *Azotobacte*r, *Azospirillum*, phosphorus solubilizing organism, and *Rhizobium.* Microbial population was counted using indirect method of Santoso and Subowo (1990). This method was initiated by isolation of soil microbes and growing the isolated microbes on agar media. Population of *Azotobacte*r, *Azospirillum*, and *Rhizobium* were observed based on number of colony on Yeast Mannitol Agar + Congo-red (YMA+congo-red) or YMA+Bromthymol-blue media. The populations were then converted to per gram of soil. Observation of phosphorus solubilizing organism population was based on number of colony on Pikovskaya media. Observation of soil worms was made on field directly by counting number of their population in square meter and soil tillage layer at 25 cm depth. Activity of soil worm was also counted based on amount of their feces. Variable of soil productivity was observed based on several parameter i.e. biomass of each plant observed on actively vegetative phase, flowering phase, formation of pod/fruit and harvesting time, and yield total of each plant per plot.

Results and Discussion

Determination of organic fertilizer doses that gave maximum contribution to increase of soil productivity on planting design system applied was made by observation of soil fertility variables, growth and yield of plants. Effect of treatments on growth and yield of plant variables and on soil properties are presented in Tables 1, 2, 3, 4, 5, and 6.

Application of organic fertilizer affected plant dry weight per plot but did not affect ratio of root obliterate. Application of 15-25 t organic fertilizers/ha yielded higher plant dry weight than applicatoion of 0-10 t organic fertilizers/ha. Yield of plant dry seeds at treatments with application of 20-25 t organic fertilizers/ha was higher than that of applied with 0-15 t organic fertilizer/ha. Data presented in Table 2 show the better effect of dry field rice residues on growth and yield of soybean compared to maize residues. Application of 15-25 t organic fertilizer/ha also significantly affected growth and yield of soybean planted after dry field rice.

Table 1. Effect of organic fertilizer doses to plant dry biomass weight, ratio of root obliterate (NPA), and yield of dry seeds per plot of maize and dry field rice

Treatment	**Maize**			**Dry field rice**		
	Plant dry biomass weight (kg)	**Ratio of root obliterate (NPA)**	**Yield of dry seeds per plot (kg)**	**Plant dry biomass weight (kg)**	**Ratio of root obliterate (NPA)**	**Yield of dry seeds per plot (kg)**
0 t/ha	3.04 a	1.76	1.60 a	2.71 a	1.84	0.84 a
5 ton/ ha	3.21 a	1.84	1.73 a	2.64 a	1.92	1.22 a
10 t/ha	4.22 a	2.31	2.14 a	3.82 a	2.32	1.61 a
15 t/ha	8.90 b	2.73	4.43 b	6.93 b	2.61	2.24 a
20 t/ha	8.91 b	2.81	6.22 c	7.04 b	2.68	4.84 b
25 t/ha	9.24 b	3.04	6.04 c	7.28 b	2.74	4.92 b
LSD 0,05	**4.202**	**NS**	**1.423**	**3.043**	**NS**	**2.041**

Table 2. Effect of dry field rice in-situ waste and maize and organic fertilizer doses to dry biomass, seeds yield, and NPA value of soybean, groundnut, and mungbean in dry land North Lombok

	Soybean			**Groundnut**			**Mungbean**		
Treatments *)	**Plant dry biomass weight (kg)**	**Ratio of root obliterate (NPA)**	**Yield of dry seeds per plot (kg)**	**Plant dry biomass weight (kg)**	**Ratio of root obliterate (NPA)**	**Yield of dry seeds per plot (kg)**	**Plant dry biomass weight (kg)**	**Ratio of root obliterate (NPA)**	**Yield of dry seeds per plot (kg)**
J_1p_0	1.76 a	0.36 a	0.78 a	2.48 a	1.67 a	1.20 a	2.22 a	1.02 a	0.22 a
J_1p_1	3.56 b	0.54 a	0.83 a	2.60 a	1.68 a	1.32 a	2.34 a	1.28 a	0.34 a
J_1p_2	3.78 b	1.12 ab	0.36 a	6.28 b	4.10 cd	2.28 ab	4.88 b	2.45 b	0.68 a
J_1p_3	5.44 c	2.16 b	1.29 ab	9.26 c	4.40 cd	4.33 c	6.96 cd	3.20 c	1.80 b
J_1p_4	5.52 c	2.41 b	2.05 ab	9.22 c	4.62 cd	4.60 c	7.08 cd	3.41 cd	1.90 b
J_1p_5	5.60 c	2.66 b	2.66 b	9.66 c	4.81 d	4.90 c	7.14 d	3.98 d	2.94 c
J_2p_0	2.08 ab	0.60 a	0.82 a	2.47 a	1.04 a	0.98 a	1.12 a	1.12 a	0.24 a
J_2p_1	3.08 ab	0.74 a	1.17 ab	3.00 a	1.24 a	1.17 a	1.22 a	1.19 a	0.30 a
J_2p_2	4.02 bc	1.08 ab	2.16 ab	3.04 a	2.64 b	1.43 a	1.44 a	1.22 a	0.54 a
J_2p_3	4.10 bc	3.24 c	3.16 c	6.32 b	3.64 cb	2.83 ab	4.33 b	2.26 b	0.62 a
J_2p_4	5.43 c	3.62 c	4.04 c	7.20 b	3.59 c	3.10 b	5.36 bc	2.64 bc	1.84 b
J_2p_5	5.72 c	3.71 c	3.92 c	7.08 b	3.66 c	3.24 b	6.78 cd	2.82 bc	1.78 b
LSD 0,05	**1.763**	**0.864**	**1.022**	**1.804**	**0.866**	**1.121**	**1.684**	**0.701**	**0.944**

*) J_1 = the first plant (maize), J_2 = the first plant (dry field rice), P_0 s/d P_5 = organic fertilizer doses 0, 5, 10, 15, 20 dan 25 t/ha.

Weight of soybean dry seeds at this treatment ranged from 3.16 to 4.04 kg/plot, dry biomass weight ranged from 5.43 to 5.72 kg/plot with NPA value of 3.24–3.71. On the contrary, application of maize residues to all organic fertilizer treatment resulted in better yield of groundnut and mungbean than dry field rice. Average of groundnut seed weight obtained at treatment of 15-25 t organic fertilizers/ha reached 4.33 – 4.90 kg/plot, and biomass weight reached 4.33 – 4.90 kg/plot with NPA value 4.40 – 4.81.

Effect of organic fertilizer application was dominant enough to plant growth and yield and increase of soil fertility. The dominance effect of organic fertilizer examined was clear because planting design system as one of factors studied. The effect of organic fertilizers on plant growth and yield, however, was not dominant at rates of 0-10 t/ha. The planting design of maize-soybean / groundnut / mungbean and dry field rice-soybean / groundnut / mungbean did not affect plant growth and yield at treatment of 0-10 organic fertilizerst/ha.

Application of organic fertilizers increased soil pH from basic to slightly neutral (Table 3). Application of organic fertilizers also significantly increased total K, total P, and organic C contents in the soils. However, application of organic fertilizers did not significantly increase total N content, especially at treatment of planting design where dry field rice as main plant. This was probably due to the complete absorbtion of organic N by the suceeding plants. Besides, there was also weeds interference which was dominant on dry field rice-soybean/groundnut/mungbean planting design. This system was assumed to plant an important role in draining of N in the soil (Ernawati et al., 2013)

Data presented in Table 3 also show that maize-groundnut and dry field rice-groundnut planting designs had better influence on soil pH, increase of soil N-total content, and C-soil organic compared to other treatments. This was indicated by the increase of total N content from 0.84% before treatment to 1.15-1.41% after treatment of planting design with 20-25 t organic fertilizers/ha. This fact supported prior assumption that groundnut is superior as a succeding plant after maize and dry field rice on planting design system in North Lombok dry land. This was because of the ability of groundnut to increase soil productivity. Rate of 20-25 t organic fertilizer/ha was the best organic fertilizer rates for restoring soil fertility. If it was correlated with total-K-total, total-P, and CEC of the soil, the superior stated treatment also contributed to the increase of soil nutrient contents (Table 4). Application of organic fertilizers positively affected soil CEC and total-K but did not relatively affect tota-P content, especially at planting design treatment of maize-soybean/mungbean and dry field rice-mungbean with 0-15 t organic fertilizers/ha. The stable soil N, P, and K contents untill fallow period were only found for the maize-groundnut and dry field rice-groundnut planting design treatment, although the rate of organic fertilizer applied was only 5-10 t/ha.

Groundnut planted after maize was more effective in using N, P, K, C-organic originated from organic fertilizers and plant residues than that of mungbean and soybean planted after dry field rice/maize. This was indicated by the high K absorption, relative water content at pore filled in phase (KAR), dry seeds yield, plant dry weight and water use efficiency (EPA).

High dry seeds weight obtained had the same effect to K absorption. K absorption at treatment of groundnut planted after maize and dry field rice was higher than soybean and mungbean planted after maize and dry field rice. The increase of soil fertility status at this treatment allowed increase of soil water status that triggered mineralization of organic matter in the soil and activity of plant nitrate reductase enzyme. The increase of soil fertility status and water holding capacity would increase N, P, and K absorption. The increase of nitrate reductase enzyme activity would also increase activity of plant N metabolism. Improvement of plant N metabolism would increase plant growth rate and eventually increased seeds yield and plant dry biomass weight.

Plant relative water content (KAR) of groundnut planted after maize at pod formation was higher than that of planted after dry field rice, and also soybean and mungbean planted after dry field rice (Table 5). In compliance with the increase of fertility status and soil water content, groundnut growth after maize and dry field rice was in an optimum state. This was because fertility status and soil water content no longer limited for plant growth phase. Stomata conductibility is more hydro active so that water loss because of transpiration can be balance by soil water as soon as possible (Gollant et al., 1985).

Table 3. Effect of planting design and application of organic fertilizer doses to soil pH, total N, and oil organic C

Planting design treatment *)	**pH (H_2O)**						**Total N (%)**						**Organic C (%)o**					
	Fertilizer rata (t/ha)						**Fertilizer rata (t/ha)**						**Fertilizer rata (t/ha)**					
	0	**5**	**10**	**15**	**20**	**25**	**0**	**5**	**10**	**15**	**20**	**25**	**0**	**5**	**10**	**15**	**20**	**25**
Before treatment	7.56	7.56	7.56	7.56	7.56	7.56	**0.84**	**0.84**	**0.84**	**0.84**	**0.84**	**0.84**	**1.60**	**1.60**	**1.60**	**1.60**	**1.60**	**1.60**
Maize-SB	7.40	7.40	7.35	7.20	7.20	7.00	0.30	0.30	0.30	0.40	0.75	0.30	1.24	1.40	1.60	1.90	2.00	2.24
Maize-MB	7.40	7.40	7.37	7.25	7.25	7.00	0.80	0.80	0.80	1.00	1.00	0.80	1.60	1.66	1.80	2.22	2.36	2.46
Maize-GN	**7.36**	**7.23**	**7.11**	**6.80**	**6.45**	**6.35**	0.80	0.90	1.06	1.10	1.25	1.41	2.24	2.60	2.80	2.90	3.30	3.84
DFR-SB	7.50	7.50	7.43	7.40	7.26	7.10	0.18	0.30	0.38	0.50	1.05	1.18	2.10	2.24	2.30	2.45	2.50	2.74
DFR-MB	7.60	7.56	7.50	7.40	7.21	7.20	0.40	0.45	0.60	0.64	0.83	0.90	1.20	1.30	1.70	2.00	2.10	2.20
DFR-GN	7.55	7.50	7.40	7.20	7.10	6.90	0.83	0.90	0.94	1.00	1.15	1.40	2.10	2.24	2.40	2.55	2.60	2.80

*) SB= soybean, MB= mungbean, GN= groundnut, DFR= dry field rice

Table 4. Effec of planting design and application of organic fertilizer doses to K-total, P-total, and soil CEC in dry land

Planting design treatment *)	**K_2O ppm**						**P_2O_5 ppm**						**CEC** (me/100 g soil)					
	Fertilizer rata (t/ha)						**Fertilizer rata (t/ha)**						**Fertilizer rata (t/ha)**					
	0	**5**	**10**	**15**	**20**	**25**	**0**	**5**	**10**	**15**	**20**	**25**	**0**	**5**	**10**	**15**	**20**	**25**
Before treatment	**2.66**	**2.66**	**2.66**	**2.66**	**2.66**	**2.66**	**3.71**	**3.71**	**3.71**	**3.71**	**3.71**	**3.71**	**22.72**	**22.72**	**22.72**	**22.72**	**22.72**	**22.72**
Maize-SB	1.10	1.10	1.50	2.90	2.90	3.10	3.40	3.40	3.80	4.00	4.10	4.16	20.24	20.36	21.40	22.88	23.90	24.24
Maize-MB	1.10	1.10	1.50	2.90	2.90	3.10	3.30	3.30	3.60	3.84	4.00	4.10	21.40	21.46	21.60	22.40	22.60	23.40
Maize-GN	**1.30**	**2.00**	**2.80**	**3.40**	**3.60**	**4.10**	**3.65**	**3.90**	**4.15**	**4.35**	**4.54**	**4.70**	**22.20**	**22.76**	**23.60**	**24.88**	**26.00**	**26.24**
DFR-SB	1.00	1.00	1.40	1.80	2.00	2.20	3.04	3.08	3.10	3.18	3.30	3.44	20.20	20.32	20.40	20.60	20.72	21.20
DFR-MB	1.10	1.10	1.50	2.00	2.10	2.34	3.08	3.14	3.25	3.40	3.48	3.66	20.24	20.36	20.60	20.88	20.90	21.24
DFR-GN	1.20	2.00	2.80	3.10	3.24	3.36	3.15	3.40	3.65	3.74	3.90	4.15	21.40	21.46	22.60	22.80	22.92	23.40

Table 5. Effect of planting design and application of organic fertilizer doses to plant K absorption, water use efficiency (EPA), and relative water content on leaves (KAR) of groundnut, soybean, and mungbean

Planting design treatment	**K absorption per plot (g)**						**EPA (g/L)**						**KAR (g/ kg) at pore filled up**					
	Fertilizer rata (t/ha)						**Fertilizer rata (t/ha)**						**Fertilizer rata (t/ha)**					
***)**	**0**	**5**	**10**	**15**	**20**	**25**	**0**	**5**	**10**	**15**	**20**	**25**	**0**	**5**	**10**	**15**	**20**	**25**
Maize-SB	9.38b	16.00b	16.81b	27.32ab	30.88a	34.15a	0.66a	0.70a	0.73a	0.81b	0.84b	0.85b	728a	750a	766a	782ab	812ab	836b
	(a)	(b)	(b)	(c)	(c)	(c)	(a)	(a)	(ab)	(b)	(b)	(b)	(a)	(a)	(ab)	(b)	(bc)	(c)
Maize-MB	4.82a	13.41ab	4.00a	28.21ab	29.49a	31.62a	0.70a	0.77a	0.80a	0.86b	0.90b	0.90b	682a	712a	732a	744 a	756 a	781a
	(a)	(b)	(a)	(c)	(c)	(c)	(a)	(a)	(ab)	(b)	(b)	(b)	**(a)**	**(ab)**	**(b)**	**(bc)**	**(c)**	**(d)**
Maize-GN	14.74c	20.31c	30.52c	38.88c	41.82b	42.64b	0.71a	0.77a	0.80ab	0.84b	0.92bc	0.98c	**742a**	768a	788a	832 b	860 b	892b
	(a)	(a)	(b)	(bc)	(c)	(c)	(a)	(a)	(ab)	(b)	(bc)	(c)	**(a)**	(ab)	(b)	(c)	(c)	(d)
DFR-SB	4.22a	10.04a	14.55b	21.74a	30.15a	33.73a	0.68a	0.72a	0.83ab	0.86b	0.90 b	0.90b	674a	702a	716a	734a	761a	770a
	(a)	(ab)	(b)	(c)	(d)	(d)	(a)	(a)	(ab)	(b)	(b)	(b)	(a)	(b)	(b)	(bc)	(c)	(c)
DFR-MB	4.53 a	11.72 a	15.00	26.33ab	31.06a	32.11a	0.60a	0.66a	0.71a	0.78ab	0.84 b	0.90b	644a	684a	701a	704a	722 a	764a
	(a)	(ab)	(b)	(a)	(d)	(d)	(a)	(a)	(ab)	(b)	(bc)	(c)	(a)	(b)	(bc)	(bc)	(c)	(d)
DFR-GN	10.34b	18.80bc	27.66c	30.14 b	34.62a	36.60ab	0.65	0.70ab	0.76 b	0.80bc	0.84bc	0.88c	721a	730a	742a	760 a	776a)	794a
	(a)	(b)	(c)	(cd)	(cd)	(d)	(a)	(a)	(ab)	(b)	(bc)	(c)	(a)	(a)	(ab)	(b)	(bc)	(c)

*) SB= soybean, MB= mungbean, GN= groundnut, DFR= dry field rice

In relation to that, water potential gradient can be maintained and eventually groundnut KAR planted after maize was higher than soybean and mungbean KAR planted after dry field rice and maize. Further, because roots can extract more water, absorption of nutrients increased and at the end can affect water use efficiency (EPA). Water use efficiency by groundnut planted after maize and dry field rice with 20-25 t organic fertilizers / ha was higher than any other treatments. Because of improvement of fertility status and soil water content at superior treatment, the sufficiency of N, P, K contents, and the increase of N metabolism triggered a better growth of upper plants, especially leaves. There was a balance between high K absorption that supported high yield of dry seeds and plants received less water during growth phase. Therefore, the use of water by plants was efficient.

Application of organic fertilizer with superior planting design also suppressed soil degradation rate through increase of physical fertility status and soil biology. This was proved from roots distribution in 0-40 cm depth. At treatment of maize-groundnut planting design with 20-25 t organic fertilizer /ha, roots distribution were found until 30 cm depth. This was better than other treatments. At this superior treatment, soil volume weight was smaller and soil porosity was greater compared to soil before treated. Water content at any pF value also increased. Rapid drainage pores decreased but slow drainage pores and soil permeability significantly increased. The highest permeability reached at maize-groundnut-fallow planting design with 20-25 t organic fertilizers / ha was about 0.89-0.91. Implication for better variable component of soil physic characteristic was able to increase irrigation efficiency (EPA) especially at treatment of maize-groundnut planting design reached 0.98. The more slow drainage pores and soil permeability ere increase, the stronger was the soil water holding capacity. Water became longer in plant roots gradient so that more water would be absorbed by plants and plant EPA value would be higher.

Treatment of maize-groundnut-fallow planting design with 20-25 t organic fertilizer /ha was also able to increase soil biology. This was proved by population of soil worms at maize-groundnut-fallow planting design with 20-25 t organic fertilizers/ha was higher than any other treatments. On this treatment, average of soil worm found was 2.44 per meter square (Table 6).

Table 6. Effect of planting design and organic fertilizer doses application to soil warms population (m^2) and average of bacterial population per gram soil (10^6)

Variables	Planting design treatment *)	Treatment of organic fertilizer doses (t/ha)					
		0	5	10	15	20	25
Population of soil warms per square meter	Maize-SB	0.01	0.04	0.20	0.40	0.70	1.10
	Maize-MB	0.01	0.06	0.44	0.46	0.80	1.00
	Maize-GN	**0.02**	**0.08**	**0.94**	**1.88**	**1.74**	**2.44**
	DFR-SB	0.01	0.05	0.40	0.66	0.80	1.10
	DFR-MB	0.01	0.04	0.54	0.76	0.88	0.90
	DFR-GN	0,01	0,07	0,75	0,90	1,20	1,40
Average of bacterial cell x 10^6 per gram soil	Maize-SB	0.342	0.862	0.971	1.120	1.244	1.420
	Maize-MB	0.161	0.783	0.894	1.021	1.320	1.364
	Maize-GN	**0.432**	**1.023**	**1.132**	**2.034**	**3.141**	**3.284**
	DFR-SB	0.104	0.264	0.710	0.873	0.975	0.982
	DFR-MB	0.123	0.324	0.764	0.800	0.872	0.900
	DFR-GN	0.321	0.912	0.962	1.431	1.652	1.754
Average of colony formation	Maize-SB	114.65	120.44	222.34	341.22	357.44	367.28
	Maize-MB	104.54	112.72	243.41	366.53	376.90	382.12
	Maize-GN	**127.71**	**144.56**	**324.81**	**520.73**	**524.45**	**545.78**
	DFR-SB	98.84	101.12	146.77	183.12	285.52	298.74
	DFR-MB	110.46	119.67	132.44	200.24	300.72	316.72
	DFR-GN	**114.34**	**137.63**	**304.73**	**345.77**	**387.83**	**402.32**
Average of colony formed *Holozone*	Maize-SB	0.01	0.01	0.12	0.74	7.84	8.62
	Maize-MB	0.01	0.01	0.08	0.62	4.04	4.23
	Maize-GN	**0.04**	**2.66**	**4.34**	**14.54**	**19.08**	**19.66**
	DFR-SB	0.01	0.01	0.10	4.32	9.42	12.51
	DFR-MB	0.01	0.01	1.12	1.45	3.87	4.11
	DFR-GN	**0.02**	**0.01**	**1.45**	**13.23**	**17.83**	**18.62**

*) SB= soybean, MB= mungbean, GN= groundnut, DFR= dry field rice

The highest bacterial population was also obtained from this treatment that had ability to grow after re-isolation and in vitro. Amount of colonies and phosphorus solubilizing bacteria population were found higher at treatment of dry field rice-groundnut-fallow planting design with 25 t organic fertilizers/ha than other treaments. It could be seen from amount of colony surrounded by holozone was founded the highest at this treatment. High population of soil worms and bacteria at this treatment was assumed to be related wih soil fertility, especially availability of organic matter as source of their nutrients. Organic matter content at this superior treatment was 3.84%.

Conclusion

Application of 20-25 t organic fertilizers t/ha on planting design of maize-nut-fallow or on planting design of dry field rice-nut-fallow, was the best planting system for overcoming soil degradation problems in dry land areas of Lombok.

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