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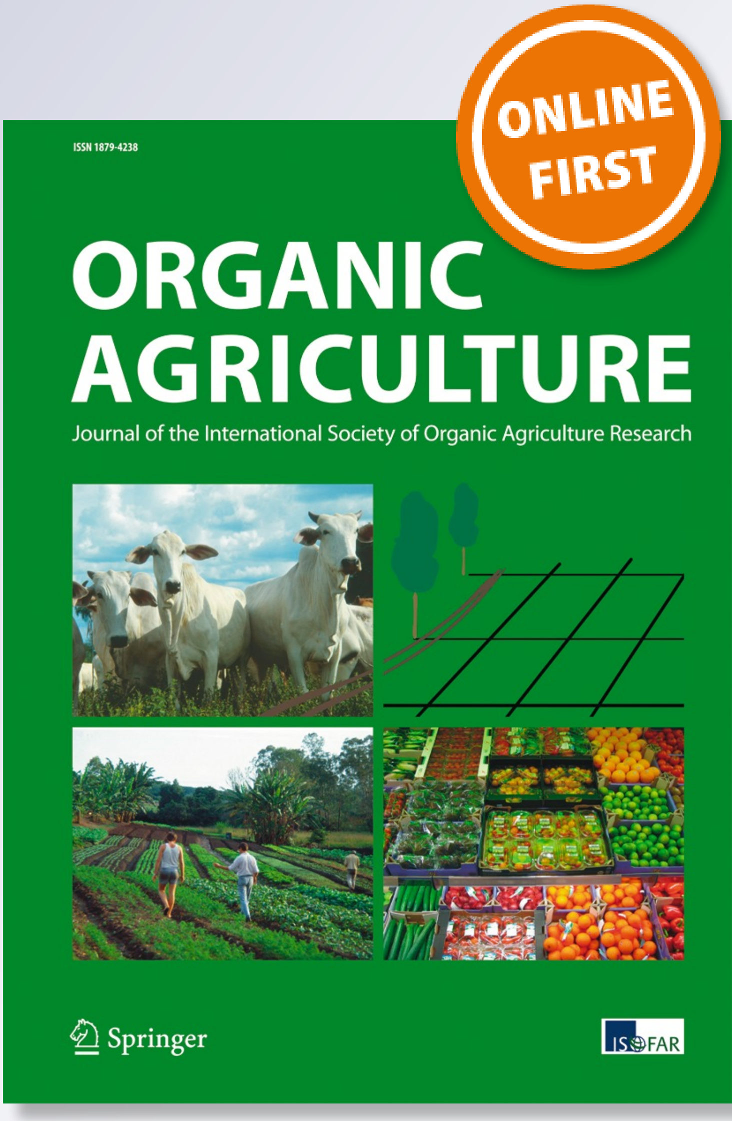

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Effects of farmyard manure and activated effective microorganisms on rain-fed upland rice in Mwanza, Tanzania

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Abstract The study was conducted to analyse and compare nutrient contents of farmyard manure, farmyard manure treated with effective microorganisms and effective microorganism solutions, also, to determine the effect of farmyard manure and activated effective microorganisms on rice growth, development and yield. Farmyard manure and effective microorganism solutions were characterized for nutrient status in the laboratory. A 3 × 3 factorial experiment in randomized complete block design and replicated thrice involved farmyard manure and activated effective microorganisms. Farmyard manure at rates 0, 5 and 10 t ha^{-1} was applied 2 weeks before sowing by broadcasting and incorporated into the soil. Activated effective microorganism solution at 0, 20 and 40 l ha^{-1} was sprayed weekly at vegetative stage. Farmyard manure and effective microorganism solution contained both macro- and micronutrients at varying proportions. Application of farmyard manure increased rice yields from 1.35 to 3.31 t ha^{-1}, 1.35 to 3.03 t ha^{-1} activated effective microorganism solution, and 1.35 to 3.33 t ha^{-1} in both farmyard manure and activated effective microorganisms when integrated. Adoption of organic soil amendments would improve soil fertility for sustainable crop production to small-scale farmers.

Keywords Effective microorganisms · Farmyard manure · Organic manure · Rice ecosystems · Upland rice

Abbreviations

EM	Effective microorganism solution
FYM	Farmyard manure
NERICA	New Rice for Africa

Introduction

Farmyard manure is gaining popularity in soil fertility improvement especially in the Lake Zone of Tanzania where most of small-holder farmers keep livestock. Application of farmyard manure in lowland rice production systems has been observed to be among the important practices in increasing yields (Kajiru et al. 2011). Following the climate changes and increased drought incidences in Tanzania, research efforts have been undertaken to introduce upland rice varieties like New Rice for Africa (NERICA) series (MAFC 2009). Some of the upland rice varieties recommended in Mwanza and Tanzania in general include NERICA1, NERICA2, NERICA4 and WAB. Researches on agricultural practices to improve soil fertility are not well covered in upland rice ecosystem. The use of organic fertilizers and other soil organic amendments is still required in upland rice production system in Mwanza and Lake Zone Tanzania.

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Rice is the second widely cultivated cereal food crop in Tanzania after maize in terms of households, area and volume of production (MAFC 2009; Mghase et al. 2010) and ranks first in Lake Zone. It is grown under three major ecosystems, namely rain-fed low land (74 %), upland (20 %) and irrigated (6 %) of the area under rice production (MAFC 2009; Kajiru et al. 2011; Kanyeka et al. 1994). Based on land and water management practices, lands suitable for rice production are classified as lowland and upland (Kajiru et al. 2011).

Upland rice refers to rice grown on both flat and sloping fields that are not bunded, prepared and seeded under dry conditions and that depend on rainfall for moisture (De Datta 1975; Fageria et al. 1997). Upland rice does not need water ponding in the fields during the rice growing cycle (Fageria 2010). The overriding difference distinguishing upland from lowland rice farming systems is the soil moisture regime. In upland rice, soils are neither submerged nor saturated with water for any appreciable part of the growing season (Fageria et al. 1997). New rice for Africa (NERICA) is an interspecific hybrid between the local African rice (*Oryza glaberrima* Steud.) and the exotic Asian rice (*Oryza sativa* L). This incorporates both the high yielding ability of *O. sativa* and the resistance of *O. glaberrima* to major constraints such as diseases, drought and low soil fertility (Africa Rice Center 2008; Mghase et al. 2010; Wopereis et al. 2008). Most of the NERICA varieties have high yielding potential and drought tolerance with short growing cycles of about 100 days (Africa Rice Center 2008).

Moisture stress, low soil fertility and improper agronomic practices are the major constraints to sustainable rice production in Tanzania. Up to 2008, the yield levels were 0.5, 1.0 and 2.13 t ha^{-1} for rain-fed upland rice, rain-fed lowland rice and irrigated lowland rice production, respectively, with an average yield of 1.3 t ha^{-1} (MAFC 2009). However, the yield is much lower than the world average of 4.4 t ha^{-1} (FAO 2010). In Tanzania, the low rice yield is due to soil moisture stress, low soil fertility and improper nutrient management practices (Mghase et al. 2010), resulting in food insecurity and low income generation.

Organic fertilizers and organic soil amendments provide a wide range of plant nutrients (Sanginga and Woomer 2009). Organic manures are materials largely of plant or animal origin in different stages of decomposition that are added to the soil to supply plant nutrients and improve the soil's physical, chemical and biological properties (Prasad and Power 1997). Farmyard manure is a heterogeneous composted organic material consisting of animal dung, urine and bedding materials, crop residue, and/or household sweepings in various stages of decomposition that contains both macro- and micronutrients required for plant growth (Satyanarayana et al. 2002). Farmyard manure considerably improves plant nutrient uptake, resulting into increased growth, development and crop yields (Pandey et al. 1999).

Alternatively, the effective microorganism technology can be used in soil fertility management because it is simple to prepare and needs locally available materials that every farmer can afford, and it has higher plant nutrient contents than other organic fertilizers like farmyard manure (Saidia et al. 2010; Takash et al. 1999). Effective microorganisms (EM) as liquid microbial inoculants contains assorted culture of beneficial fermentative microorganism such as lactic acid bacteria (*Lactobacillus* spp.), yeast (*Saccharomyces* spp.), photosynthetic bacteria (*Rhodopseudomonas* spp.), actinomycete and fermenting fungi (Fatumbi and Ncube 2009; Takash et al. 1999).

Lactic acid bacteria produce lactic acid from sugars and other carbohydrates developed by photosynthetic bacteria and yeast. Lactic acids have powerful sterilizing properties, suppress harmful microorganisms and encourage quick breakdown of organic substances. Lactic acid bacteria can suppress the reproduction of *Fusarium*, a harmful fungus as well as pests like nematodes in a continuous cropping programme (Fatumbi and Ncube 2009; Takash et al. 1999). Yeasts such as *Saccharomyces* manufacture anti-microbial and useful substances like vitamins, enzymes and hormones for plant growth (Jilani 1997). Metabolites from yeast such as amino acids, nucleic acids and sugars are food for other bacteria such as the lactic acid and actinomycete groups (Fatumbi and Ncube 2009; Takash et al. 1999). *Actinomycetes* suppress the proliferation of harmful microorganisms such as *Fusarium*, *Verticillium*, *Pythium* and other harmful fungi and bacteria. In addition, *Actinomycetes* can live together with photosynthetic bacteria such as *Rhodopseudomonas*.

The photosynthetic bacteria synthesize useful substances from secretions of roots, organic matter and/or harmful gases such as hydrogen sulphide by using sunlight and the heat of soil as sources of energy. Therefore, they contribute to a better use of sunlight consequently increased photosynthesis (Fatumbi and Ncube 2009; Takash et al. 1999). Metabolites developed and produced by these microorganisms, for example, amino acids, nucleic acid, bioactive substance and sugars, are directly absorbed by plants. These metabolites also act as substrate or food for other microorganisms such as vesicular *Arbuscular mycorrhizae*, *Azotobacter*, *Rhizobium* and others in the soil. Hence, the number of beneficial microorganisms increases in the soil ecosystem and the ability of plants to fix atmospheric nitrogen increases. Thus, plant nutrients like nitrogen and phosphorus become available to plants (Fatumbi and Ncube 2009). Jilani (1997) reported that fermenting fungi such as *Saccharomyces*, *Trichoderma* and *Mucor* break down the organic substances like cellulose, starch, gums, lignin and phospholipids into humus, organic acids and plant nutrient elements at an increased rate, thus suppressing the smell and preventing damage that could be caused by harmful insects (Fatumbi and Ncube 2009; Higa and Kanal 1998; Takash et al. 1999).

Adoption of farmyard manure at varying rates would probably increase upland rice production in all areas where livestock are being kept and farmers can easily access farmyard manures for sustainable farming. In areas where livestock are not kept, effective microorganism technology can be used for sustainable crop production. Also decomposing farmyard manure with effective microorganism solution would improve the quality of manure. However, integrated application of farmyard manure and effective microorganism technology could sustain soil fertility improvement in a long run and improve rain-fed upland rice production to small-scale farmers.

Objectives of the study were (a) to analyse and compare the nutrient contents of farmyard manure, farmyard manure treated with effective microorganisms and effective microorganism solutions and (b) to determine the effect of farmyard manure and activated effective microorganisms on rice growth, development and yield.

Materials and methods

Location

The study was conducted in 2011 to 2012 at Ukiriguru, Mwanza, Tanzania (2° 43.1′ S, 33° 1.0′ E) which is located at an altitude of 1198 m above sea level. Ukiriguru lies within the dry savannah zone, and the soils range from granitic hill sands to heavy clays in the valley bottoms (Nyambo 1983). The area experiences a bimodal rainfall pattern: short-term rains locally known as “vuli” from October to January followed by a dry spell of about 2 weeks and a long-term rain locally known as “masika” which starts from February to June. Maximum temperature during 2011/12 cropping season was between 26.5 and 30.83 °C while minimum temperature was in the range between 18.4 and 18.98 °C. Rainfall was 84.2, 124.5, 171, 6.6, 57, 36.5 and 192 mm in October, November, December, January, February, March and April, respectively. The experimental site was previously used for cotton cultivation for demonstration purpose during which synthetic chemical fertilizers, namely urea, sulphate of ammonia (SA) and triple super phosphate (TSP) were applied prior to the current study (Kileo and Malagila, pers comm.).

Materials

Materials used in this study included upland rice NERICA4 variety, FYM and effective microorganisms (EM).

Farmyard manure (FYM) was collected from livestock keepers at Ukiriguru. Some of the collected FYM were used to prepare compost farmyard manure treated with effective microorganism solutions by pouring 150 mL of EM solutions into a sample of collected cattle manure. EM-1 as a concentrated solution of effective microorganisms (Fatumbi and Ncube 2009; Takash et al. 1999) and farmyard manure were mixed thoroughly in a 10-L bucket. Also, EMA was mixed thoroughly with another sample of farmyard manure in a 10-L bucket. These buckets were closed tightly to decompose for 11 days. Then, farmyard manure samples from each bucket were taken into the laboratory for nutrient analyses.

Effective microorganism (EM) solution was collected from Bustaniya Tushikamane Morogoro and was used to prepare activated effective microorganisms (EMA). EMA was prepared from 1 L EM-1, 1 L molasses and 18 L clean water (free from chlorine and dirt) in a 20-L bucket as proposed by Saidia et al. (2010) and Takash et al. (1999). Water was boiled to about 35 °C to facilitate mixing of materials. Molasses was dissolved first in 5 L of water and poured into a clean 20-L plastic bucket. Then, EM-1 was added and water topped to get 20 L, and the ratio was 1:1:18 for EM-1, molasses and water, respectively. The bucket was closed tightly and stored in a cool place for 10 days. Then, EMA was ready for use when the pH was between 3.0 and 3.9. The pH meter and strips were used in monitoring the pH of EM. Some of EMA solution was taken into the laboratory for nutrient analysis while the remaining was applied in the upland rice field.

Characterization of farmyard manure and effective microorganism solution

Characterization of FYM and FYM+ EM solutions as composts was based on the determination of total nutrient elemental composition. Analyses of manures were carried out on dried and ground samples where the sulphuric acid wet digestion method was used. Also, characterization of EM and EMA was done in order to determine nutrient status. The procedures used were those proposed by Okalebo et al. (1993). The nutrient elemental composition of the farmyard manures and effective microorganisms determined were organic carbon, nitrogen, phosphorus; exchangeable bases like potassium, calcium, sodium and magnesium; and micronutrients like copper, zinc, iron and manganese. These were used to establish the quality of the conventional farmyard manure, FYM + EM and EM solutions in terms of plant nutrients.

The field experiment

A 3 × 3factorial experiment in randomized complete block design was conducted at Ukiriguru in Mwanza to assess the response of upland rice NERICA variety to farmyard manure and activated effective microorganism solution (EMA) as recommended by Gomez and Gomez (1984) and Montgomery (2004). Farmyard manure (kraal manure) was applied at 0, 5 and 10 t ha^{-1} on oven dry weight basis, a 5 t ha^{-1} farmyard manure was a benchmark used by farmers in lowland rice ecosystem in Lake Zone of Tanzania. EMA was sprayed at 0, 20 and 40 L ha^{-1}, the rate of 20 L ha^{-1} was taken as a benchmark for application (Takash et al. 1999). Three replications were used and the treatment plot dimension was 4.5 m^2. The upland rice plant spacing was 0.3 m × 0.15 m in the experiment.

Farmyard manure was uniformly broadcasted and then incorporated into the soil 2 weeks before planting due to slow and gradual release of nutrients as suggested by Temba (1999). EMA was sprayed on rice plants as a foliar application 5 days after emergence (5 DAE) up to beginning of flowering (84 DAE). EM spraying was scheduled once per week as described by Takash et al. (1999) and Saidia et al. (2010). The dilution rate for EMA in water was 1: 500 to avoid yellowing of foliage due to too low pH of the EMA (Takash et al. 1999). Agronomic practices such as weeding were carried out timely as recommended.

Data collection

Number of tillers

This is a number per unit area or the number of tillers per plant when single-plant hills have been used. This was obtained by counting the number of stems or tillers in each hill including the main tiller in all hills in a sampled area of 1 m^2 (Gomez 1972). The number of tillers in treatments was recorded at tillering and flowering growth stages.

Leaf area index

Leaf area index (LAI) at flowering stage was obtained by selecting four central hills, and then in each hill, a main tiller was selected. The number of leaves was counted per main tiller; length and width of leaves were measured and the number of tillers in a sampled area of 1 m^2 was taken as described by Harding and Jalloh (2011). The information thus recorded was used to calculate LAI using the equation by Yoshinda (1981) as follows:

$$\mathrm{LAI} = K\left(\frac{\text{Total number of tillers} \times \text{Average leaf area} \times \text{Number of leaves per tiller}}{\text{Area of land covered by total number of tillers}}\right) \tag{1}$$

where

LAI leaf area index and
K 0.75 (constant)

Above-ground biomass and harvest index

Biomass and harvest index (HI) at maturity phase were obtained by the procedures described by Fageria (2010). Plants in a sampling area of 1 m^2 were cut 5 cm above the ground, sun dried for 3 days and measured to get the weight of total biomass above the ground then threshed to get grains only, these grains were also measured to get the weight of grains. Then, grain HI was obtained using the relationship established by Fageria (2010) and Fageria et al. (2011) where

$$HI = \frac{\text{Grainweight}(g)}{\text{Total weight above ground}(\text{Grain} + \text{Straw})g} \quad (2)$$

Yields of upland rice

Biological and economical yields were measured at harvest maturity. An area of about 1 m^2 was sampled where a number of panicles were recorded, and rice was harvested. The number of spikelets and grains per panicle was recorded; the percentage of filled grains was obtained through a relationship between the number of filled grains and the total number of grains per panicle. In addition, 1000 grains were counted and measured to get a weight of 1000 grains (g) by the procedures described by Gomez (1972). Then, a grain yield of upland rice was obtained from the relationship by Fageria et al. (1997) and Yoshinda (1981):

$$GY = \left(P \times SP \times FS \times 1000GW \times 10^{-5}\right) \quad (3)$$

where

GY grain yield (t ha^{-1})
P number of panicle m^{-2}
SP number of spikelet per panicle
FS Percentage filled spikelet or grains, and
GW 1000-grain weight (g)

In addition, yield was obtained by measuring the above-ground total dry matter per metre square area; Ceesay (2004) related this in the equation:

$$\text{Yield} = \text{Total dry matter (TDM)} \times \text{Harvest index (HI)} \quad (4)$$

Data analysis

Data collected in the field were subjected to descriptive and inferential statistics for analysis, whereby mean, coefficient of variation, standard errors and an estimate of a population from the samples were used. Analysis of variance (ANOVA) was used to test the effects of FYM and activated effective microorganisms (EMA) applications based on the statistical model:

$$Y_{ijkl} = \mu + a_i + b_j + ab_{ij} + \varepsilon_l \quad (5)$$

where

Y_{ijkl} Response
μ General mean
a_i Main effect of FYM treatment
b_j Main effect of EMA
ab_{ij} Interaction effect of FYM and EMA, and
ε_l Error term effect in accordance with the procedure described by Gomez and Gomez (1984) and Montgomery (2004).

Then, mean comparison procedures were based on Tukey's test, this method has a low false-positive rate (type I error), more powerful and controls the overall error rate (Montgomery 2004), treatments were compared at $P \leq 0.05$. GenStat (2011) was used to analyse data.

Results

Properties of the farmyard manure and effective microorganism solutions

The EM technology was including effective microorganism solution (EM-1) and activated effective microorganism (EMA) solution. The pH, organic carbon, nitrogen, phosphorus, potassium, calcium, magnesium, sodium, copper, iron, zinc and manganese values in the EM-1 and EMA, and molasses to some extent are as shown in Table 1. EMA had high organic matter, phosphorus, potassium, sodium, copper, iron and zinc than EM-1 solution. The organic carbon content was 2.48 %

Table 1 Characteristics of the activated effective microorganisms (EMA) and effective microorganisms (EM-1) solutions used in the study

S/N	characteristic	EMA value	EM-1 value	Molasses value
1	pH	3.87	3.56	5.90
2	Electroconductivity	8.83 mS cm^{-1}	10.28 mS cm^{-1}	
3	Organic carbon	2.48 %	1.96 %	3.43 %
4	Nitrogen	8.12 mg L^{-1}	40.88 mg L^{-1}	0.24 %
5	Phosphorus	112.25 mg L^{-1}	85.05 mg L^{-1}	15 mg L^{-1}
6	Potassium	747.18 mg L^{-1}	517.3 mg L^{-1}	285 mg L^{-1}
7	Calcium	392.62 mg L^{-1}	921.58 mg L^{-1}	
8	Magnesium	61.32 mg L^{-1}	63.56 mg L^{-1}	
9	Sodium	77.51 mg L^{-1}	22.47 mg L^{-1}	
10	Copper	0.19 mg L^{-1}	0.14 mg L^{-1}	
11	Iron	13.71 mg L^{-1}	10.67 mg L^{-1}	
12	Zinc	1.73 mg L^{-1}	0.73 mg L^{-1}	
13	Manganese	0.80 mg L^{-1}	4.41 mg L^{-1}	

in EMA solution while 1.96 % in EM-1 solution. Molasses as a material for preparing EMA contained 3.43 % organic carbon. Therefore, activating effective microorganisms using molasses improved the quantity of organic matter in the solution.

The elemental composition of farmyard manure used in the study is as presented in Table 2. Farmyard manure treated with effective microorganism solutions had higher content of organic matter, nitrogen, potassium and sodium compared with conventional farmyard manure. Convention or normal farmyard manure contained more phosphorus, calcium, magnesium, copper, zinc and manganese. Treating farmyard manure with effective microorganism solutions and allowing it to decompose for a period of less than 2 weeks improved some nutrient contents. Effective microorganism solutions improve quality of manure for about twofolds in terms of organic matter content. Normal farmyard manure contained 6.91 % organic carbon while farmyard manure treated with concentrated effective microorganism solution (EM-1 farmyard manure) and

Table 2 Characteristics of the farmyard manure and manure treated with activated effective microorganisms (EMA) and effective microorganisms (EM-1) solutions

S/N	Characteristic	Farmyard manure value	EM-1 farmyard manure value	EMA-farmyard manure value
1	pH	8.69	9.67	9.53
2	Electroconductivity (mS cm^{-1})	4.76	3.89	4.11
3	Organic carbon (%)	6.91	11.72	12.36
4	Total nitrogen (%)	0.94	1.38	1.33
5	C/N ratio	7.5	8.5	9.4
6	Total phosphorus (%)	0.48	0.37	0.37
7	Total potassium (%)	0.37	0.95	0.78
8	Total calcium (%)	1.66	0.99	1.19
9	Total magnesium (%)	0.33	0.20	0.31
10	Total sodium (%)	0.04	0.11	0.06
11	Copper (mg kg^{-1})	170.75	5.45	5.45
12	Iron (mg kg^{-1})	1278.6	1191.05	1796.20
13	Zinc (mg kg^{-1})	121.82	21.65	56.80
14	Manganese (mgKg^{-1})	469.77	166.70	332.60

Table 3 Nutrient content of manure used in the field

Nutrients (kg/ha) → manure (t/ha) ↓	N (kg)	P (kg)	K (kg)	Ca (kg)	Mg (kg)	Na (kg)
5 t farmyard manure	47	24	18.5	83	16.5	2
10 t farmyard manure	94	48	37	166	33	4

activated effective microorganism solution (EMA-farmyard manure) contained 11.72 and 12.36 %, respectively. Total nitrogen was 0.94 % in normal farmyard manure which provided 47 kg N ha^{-1} when 5 t manure ha^{-1} was applied (Table 3). However, 1.38 % in EM-1 farmyard manure and 1.33 % in EMA-farmyard manure (Table 2) are noted. Potassium content was 0.37 % in normal farmyard manure, 0.95 % in EM-1 farmyard manure and 0.78 % in EMA-farmyard manure. However, the content of phosphorus was high for about 0.11 % in normal farmyard manure compared with manure treated with effective microorganism solutions. Therefore, treating farmyard manure with effective microorganism solutions is a good technique of handling manure and improving its quality.

Influence of farmyard manure and activated effective microorganisms on growth and yield of upland rice

The effect of FYM and activated EMA solution as organic soil amendment was significant on upland rice NERICA4 variety in terms of number of tillers, leaf area index (LAI), above-ground biomass production, harvest index (HI), grain weight and yields as presented in Table 4. Both main and interaction effects of FYM and

Table 4 Effect of farmyard manure (FYM) and activated effective microorganisms (EMA) on number of tillers per plant, leaf area index (LAI), biomass production and grain yield

Treatments	Tillers	LAI	Biomass (kg m^{-2})	HI	1000-grain weight (g)	Grain yield (t ha^{-1})
FYM (t ha^{-1})						
0	5.25a	0.36a	0.37a	0.43a	21.47a	1.35a
5	7.39b	0.94b	0.61a	0.62b	26.34b	3.05b
10	7.75b	1.02b	0.62a	0.64b	26.22b	3.31b
EMA (L ha^{-1})						
0	5.25a	0.64a	0.36a	0.43a	21.47a	1.35a
20	6.91ab	0.84a	0.55a	0.61b	25.44b	2.82b
40	7.75b	1.16b	0.62a	0.63b	26.19b	3.03b
FYM × EMA (t ha^{-1} × L ha^{-1})						
0 × 0	5.75a	0.34a	0.36a	0.43a	21.47a	1.35a
0 × 20	7.25ab	0.80b	0.58b	0.54ab	25.27ab	2.30ab
0 × 40	6.67ab	1.10bc	0.55b	0.64b	25.70b	2.70b
5 × 0	8.08b	0.79b	0.71bc	0.58ab	25.80b	3.21b
5 × 20	7.08ab	0.78b	0.56b	0.62b	25.60b	2.84b
5 × 40	7.00ab	1.25c	0.58b	0.66b	27.63b	3.12b
10 × 0	7.75ab	0.96bc	0.58b	0.65b	26.27b	3.30b
10 × 20	7.42ab	0.94bc	0.54b	0.66b	26.53b	3.33b
10 × 40	8.08b	1.15bc	0.74bc	0.61b	25.87b	3.27b
GM	7.23	0.90	0.58	0.60	25.57	2.83
CV (%)	23.8	15.9	26.8	10	5.4	13.7

Figures followed by same letter(s) in columns are not significantly different at $P < 0.05$ according to Turkey's test

GM grand mean, *CV* coefficient of variation

EMA were significant except the main effect in above-ground biomass. The number of tillers per plant increased from 5 to 8 while leaf area index increased from 0.34 to 1.25. EMA was sprayed on the entire plants, and nutrients were absorbed directly by leaves and improved the size of the leaves.

The above-ground biomass production increased from 0.36 to 0.74 kg m¯2 due to interaction of FYM and EMA. HI in upland rice was increasing with applications of FYM and EMA from 0.43 to 0.66. However, the interaction effect was the highest at 5 t ha^{-1} FYM × 40 L ha^{-1} and 10 t ha^{-1} FYM × 20 L ha^{-1}. Hence, integrated application of farmyard manure and effective microorganisms is important in upland rice production.

Grain weight and yields in upland rice were increasing with application of farmyard manure and activated effective microorganisms. Thousand-grain weight increased from 21.47 to 26.34 g in FYM, 26.19 g in EMA and 27.63 g in combined application of both FYM and EMA. Also, yield increased from 1.35 to 3.31 t ha^{-1} in FYM, 3.03 t ha^{-1} in EMA and 3.33 t ha^{-1} in both FYM and EMA (Table 4). Application of farmyard manure and activated effective microorganisms improved plant growth characteristics and yield significantly in upland rice ecosystem.

Discussion

Quality of farmyard manure

Based on the percentages of total nitrogen, phosphorus and the C/N ratio, the FYM was of medium quality (Palm et al. 2001). The high P content and the C/N ratio would positively influence the rate of mineralization of the farmyard manure. A C/N ratio ≤13 is an indication that the farmyard manure used was of good quality, and net mineralization of N would be expected to occur. Also P > 0.25 % influenced net P mineralization (Palm et al. 2001).Causes of the low total N in the farmyard manure could be attributed to the inappropriate storage and handling techniques. The farmyard manure was stored in open space exposed to direct sun, rainfall and wind; as a result, nutrients like nitrogen were lost during storage. Snijders et al. (2009) reported that there is a high variation in nutrient loss during manure collection, storage, processing and application. Farmyard manure treated with effective microorganism solutions contained a higher percentage of nutrients than normal farmyard manure. This was influenced by increased microbial activities because of adding effective microorganisms in farmyard manure for 11 days.

Palm et al. (1997) and Kajiru et al. (2011) reported that high quality organic manure had N > 2.5 %, P > 0.24 %, lignin < 15 % and polyphenols <4 %. In other studies, Opala et al. (2012) rated farmyard manure having 1.8 % N, 0.4 % P and C/N ratio 20 as of medium quality in Kenya.

Characteristics of effective microorganism solution

Effective microorganisms (EM) had the lowest pH value that indicates its suitability; an EM solution with a pH value below 4.0 is a good indication of the activities of microorganisms like lactic acid bacteria in the liquid (Takash et al. 1999). The activated effective microorganisms (EMA) solution had higher organic carbon, phosphorus, potassium, sodium, copper, iron and zinc than EM-1. The EMA solution was prepared from EM-1 and molasses that contained high quantity of organic matter. EM-1 is a solution containing effective microorganisms that use molasses as a source of carbohydrate and energy; this increased microbial activities and influenced the availability of plant nutrients.

Effective microorganisms contribute to a better use of sunlight hence increased photosynthesis and grain yield to crops (Fatumbi and Ncube 2009; Takash et al. 1999). The beneficial microorganisms have the ability to enhance the decomposition and mineralization of organic residues in soils and soil organic matter that is the main mechanisms through which EM contributes to soil health and plant nutrition.

Response of rice to farmyard manure and activated effective microorganisms

Application of FYM improved growth and development of upland rice, the yield increased from 1.35 to 3.31 t ha^{-1}. Manures play important roles in improving the physical, chemical and biological properties of soils. FYM contained both macronutrients and micronutrients which are required for plant growth. Application of FYM considerably improves plant nutrient uptake, resulting into increased growth, yields and yield components in crops (Pandey et al. 1999). This is because FYM increases organic matter in the soil which increases porosity, reduces bulky density and improves rooting environment for upland rice (Gupta and O'toole 1986; Hesse 1984) with subsequent increase for the roots' capacity to scavenge for nutrients in the soil. Khan et al. (2010) found that application of FYM increased soil organic matter by about 29.9 % and improved the soil's physical and chemical properties like soil structure, moisture retention capacity and plant nutrient retention. Organic matter positively contributes to soils' aggregate stability and aeration (Khan et al. 2010; Prasad and Power 1997). Sharma (1995) reported that application of FYM at 10 t ha^{-1} contributed about 30–70 kg N ha^{-1} in rice besides leaving a significant residual effect to the succeeding crop. Further, Satyanarayana et al. (2002) reported that application of farmyard manure significantly improved tillering in rice plants by 12 %, number of filled grains by 6 %, 1000-grain weight by 9 %, grain yield by 25 % and straw yield of rice by 12 % as compared with no FYM application. Kajiru et al. (2011) found that application of FYM at 7 t ha^{-1} produced 2.17 t ha^{-1} grain yield of lowland rice in Maswa District, Shinyanga, Tanzania. Therefore, application of FYM as organic soil amendment is important for soil fertility improvement and increases crop yields sustainably.

On the other hand, application of EMA improved upland rice crop development and increased grain yield from 1.35 to 3.03 t ha^{-1}. EMA solution contained a variety of plant nutrients essentially for plant growth and development. Apart from providing nutrients directly to plants, EMA also contained effective microorganisms that enhance plant growth and development. Fatumbi and Ncube (2009) reported that the EM solution used contains beneficial microorganisms such as photosynthetic bacteria, lactic acid bacteria, yeast, fungi and actinomycete that coexist among themselves as well as with plants where the solution is applied. These effective microorganisms contributed to a better use of sunlight. Takash et al. (1999) indicated that in the presence of organic matter, photosynthetic bacteria and algae could utilize wavelengths ranging from 700 to 1200 nm that cannot be used by green plants, hence increasing photosynthesis and grain yield to crops. The beneficial microorganisms had the ability to enhance the decomposition and mineralization of organic residues in soils and soil organic matter that is the main mechanism through which EM contributes to soil health and plant nutrition (Fatumbi and Ncube 2009). Zacharia (1993) reported that the application of EM, farmyard manure and NPK gave maximum yield and increased yield components in a paddy. Furthermore, application of EM increased crop yield in a rice-wheat rotation system. Moreover, application of EM improved soil physical properties especially when applied with organic amendments in the field and green house in Pakistan (Hussain et al. 1995). Ahmad et al. (1993) observed that there was 9.5 % increase in the yield of a paddy under field condition due to application of EM. Thus, application of EMA improved soil fertility and increased crop production.

Integration of farmyard manure and effective microorganism in the field improved upland rice growth and yield from 1.35 to 3.33 t ha^{-1}. Application of both farmyard manure and effective microorganisms in soil fertility improvement and crop development is good in integrated manner. Normally, farmyard manure is incorporated in the soil while effective microorganism solution is sprayed directly to plants and the soil, hence improving soil fertility and crop development sustainably. Sharifuddin et al. (2010) reported that application of rice straw, NPK and EM increased rice yield, and harvest was 3.6 t ha^{-1} in paddy fields in Malaysia. Therefore, application of effective microorganisms with other soil fertility improving materials is important for sustainable crop production.

Conclusion

Farmyard manure used as organic soil amendment was of medium quality based on the analytical results, it contained both macro- and micronutrients. Well-decomposed manure with high phosphorus content and good C/N ratio enhanced the mineralization and nutrient release into the soil for plant growth. Activated effective microorganism (EMA) solution contained plant nutrients that are essential for plant growth. Effective microorganism solution contained microorganisms that increase the rate of decomposition of organic materials; also, coexistence of effective microorganisms increased the rate of plant nutrients in farmyard manure treated with this solution. Therefore, when FYM was treated with effective microorganism solution, the rate of decomposition increased as well as the nutrient status and quality of the materials for soil fertility improvement. Application of farmyard manure and effective microorganism solution increased the grain yield compared with control. Organic manure contains organic matter that acts as a sponge in the soil thereby improving moisture retention capacity and fertility status of the soil. Hence, organic manure such as FYM and EMA is a good organic soil amendment and appropriate application increases grain yield especially in areas with low soil fertility and poor soil moisture.

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