International Journal of Biosciences (IJB)
ISSN: 2220-6655 (Print) 2222-5234 (Online)
Vol. 2, No. 11, p. 146-165, 2012
http://www.innspub.net

RESEARCH PAPER

Influence of inorganic and organic nutrient sources on soil properties and rain-fed rice tissue nutrient content in Gambella, Ethiopia

Shiferaw Nesgea[1*], Heluf Gebrekidan[2], J. J. Sharma[2], Tareke Berhe[3]

[1]*Gambella Regional Agricultural Research Institute, P. O. Box 62, Gambella, Ethiopia*

[2]*Colleges of Agriculture and Environmental Sciences, Haramaya University, P. O. Box 138, Dire Dawa, Ethiopia*

[3]*SASAKAWA Africa Association`s Regional Rice Program, Addis Ababa, Ethiopia*

Received: 25 October 2012
Revised: 19 November 2012
Accepted: 20 November 2012

Key words: Farmyard manure, *Leucaena leucocephala*, nitrogen, phosphorus, soil/tissue nutrients.

Abstract

A field experiment was conducted in RCBD replicated trice in the main seasons of 2008-2009 at Imla, Gambella Agricultural Research Institute, Ethiopia, to evaluate the effects of four levels each of N/P (0/0, 46/23, 92/46 and 138/69 kg N/P ha^{-1}) and farmyard manure/*Leucaena leucocephala* green manure (FYM/LGM) (0/0, 5/5, 10/0 and 0/10 t ha^{-1}) on soil pH, OC, Mg and Ca and soil and NERICA-3 rice (*Oryza sativa x Oryza glaberrima*) tissue N, P, K and S contents. Soil OC, pH, N, K and Ca were decreased while the soil P, Mg and S were increased from the initial status. Application of 5/5 t FYM/LGM ha^{-1} led to the highest soil pH which increased by 9.2% than the lowest. The highest soil N, P and S (increased by 20.9, 31.4 and 54.9%, respectively, over the control) were obtained from 138/69 kg N/P ha^{-1}; while soil Mg obtained by the interaction of 46/23 kg N/P and 0/10 t FYM/LGM ha^{-1}. Ca found highest by the interaction of 138/69 kg N/P and 0/10 t FYM/LGM ha^{-1} over other treatments. Maximum soil N recorded by 5/5 t FYM/LGM ha^{-1} that increased by 27.3% over the control. Soil P, K and S values were highest with 0/10 t FYM/LGM ha^{-1} over the other treatments (increased by 24.6, 37.9 and 30.11% over their control, respectively). Highest value of tissue N and K obtained from 92/46 and 138/69 kg N/P ha^{-1} (increased by 71.2 and 44.3% over the lowest, respectively). The effects of fertilizers on tissue P were insignificant. Increased tissue S was found from 138/69 kg N/P and 5/5 t FYM/LGM ha^{-1}, representing an increase of 18.7 and 43.8% than their control. These results confirmed that organic manures could increase soil fertility and nutrient content of rice tissue, and then can be used to substitute chemical NPK fertilizers for sustainable rice production.

*Corresponding Author: Shiferaw Nesgea ✉ nesgeashiferaw@yahoo.com

Introduction

Due to fast growing of human population and progressive shrinking of per capita accessible agricultural land, demand for food is increasing than usual in Ethiopia. As most of the additional food required must come from already available cultivated land, intensification of agriculture with optimal use of nutrient inputs will be required (FAO, 2006). Even with a high degree of nutrient recycling through organics, mineral fertilizers will continue to be of central importance for meeting future food demands. Therefore, integrated use of organic and inorganic nutrient sources can improve crop productivity and sustain soil health.

Nitrogen (N), phosphorus (P) and potassium (K) are the major nutrients that are supplied by fertilizers; tend to flood the soil solution at the expense of minor ones, which produces a situation of unbalanced nutrient supply to the crop (Prakash *et al.*, 2002; Myint *et al.,* 2010). Natural resistance and fertility of soil become decline with the continued use of soluble fertilizers (Ladha *et al.*, 2000; Prakash *et al.*, 2002). Related to this, it is obvious that yield either declines or remains stagnant in spite of moderate application of the chemical fertilizers. As a consequence, soil requires more and more fertilizers to produce the same yield (Buresh and Witt, 2008). Neglecting the value of soil organic matter (OM) in crop growing and prolonged overuse of soluble inorganic fertilizers on lowering land productivity, increased crop infestation of pests and diseases, human health hazards and pollution of the environment are becoming increasingly evident. The application of inorganic fertilizers is also costly (Myint *et al.,* 2010).

Rice soil system favors fertility maintenance and builds up of soil OM, and is the backbone of long-term sustainability of the highland or lowland rice systems. Thus, organic residue recycling is becoming an increasingly important aspect of environmentally sound sustainable agriculture (Sahrawat, 2004; Myint *et al.,* 2010). Application of organic materials is fundamentally important in that they supply various kinds of plant nutrients, improve soil physical and chemical properties with its nutrient holding and buffering capacity, and consequently enhance microbial activities (Suzuki, 1997). Neither the inorganic NPK nor organic manure alone can achieve high yield objectives under intensive farming, where nutrient turnover in soil-plant system has been quite large (Mohanty and Sharma, 2000; Singh *et al.*, 2001). Singh *et al.* (2001) added, "Improvements in physical, chemical and biological properties of soil are the aims of integrated nutrient supply systems, as well as sustainable agricultural production. The concept behind integrated nutrient supply is the maintenance and adjustment of soil fertility and of plant nutrient supply with the use of both inorganic and organic fertilizers in the most efficient manner". Further, OM continuously releases N as plant need it. Nitrogen is the most limiting nutrient in rain-fed rice systems, but P and K deficiencies are also the constraints increasing yield for consecutive planting of rice (Myint *et al.,* 2010). The ability of *Sesbania* green manuring in rice and *Leucaena* green leaf manuring in wheat coupled with FYM in meeting the nutrient requirements of rice-wheat cropping system is well established (Tomar *et al.*, 1992; Sharma *et al.*, 1995; Sharma and Prasad, 1999; Gurpreet *et al.,*2007).

Therefore, use of livestock wastes and green manure in agricultural soils has been an increasing interest due to the possibility of recycling valuable components such as OM, N, P, K, etc. Although the effects of OM can be observed after 3 to 5 years (Ohyama *et al.*, 1998; Uenosono and Nagatomo, 1998), interest in agriculture production based on organic applications is growing and the demands for the resulting products are increasing. Therefore, the use of organic materials in rice farming is also likely to be promoted (Myint *et al.,* 2010).

It is now well thought out that farmers profit maximization with proper management practices to improve indigenous soil nutrient supply, reduce amount of applied fertilizer without yield loss and use of organic manures in combination with mineral fertilizer is in consideration (Palaniappan and Annadurai, 1999; Khan *et al.*, 2004; Antil and Singh, 2007; Buresh and Witt, 2008). The quantity and proportion of N, P and K required by crops can vary and thereby limit the efficiency of the organic manures. Hence, the challenge is to combine organic manures of different quality with chemical fertilizers to optimize nutrient availability to crop-plants (Palm *et al.*, 1997). Using these wastes, the fertilizer need of next crop could be reduced by 50% as reported by Rani *et al.* (1991).

Currently, except blanket recommendations with fixed rates and timings for large crop growing areas, there is no location, crop and crop stage and season specific nutrient management approaches in Ethiopia, especially in Gambella. Moreover, there is little available research and information related to NERICA-3, which is recently released in Gambella by Ethiopian Institute of Agricultural Research for its high yield and non shattering potential and wider adaptability. Therefore, one of the objectives of this work was to provide useful information to Gambella farmers on crop response to manure and fertilizer application and the nutrient status of the soil and tissue of rice at the study area. In view of the above, the present investigation was undertaken to evaluate the effect of N/P fertilizers and FYM/LGM on soil properties and nutrient concentration of rice.

Materials and methods

Description of the study site

The experiment was conducted at Imla (8° 14' 46.36'' N latitude; 34° 35' 17.75'' E longitude; altitude 450 masl) in the Gambella Peoples` National Regional State (7° 37' 06'' N and 34° 41' 22'' E), Ethiopia (Wikipedia, 2011) during the 2008 and 2009 main cropping seasons. The area is characterized by hot humid tropical lowland climate.

It has mean annual of 19.9 and 35.5 °C minimum and maximum temperatures respectively, and a mean annual rainfall of 1227.6 mm (NMA, 2009). The location map of the study area and weather data during the two experimental seasons are presented in Figs. 7.1 and 7.2, respectively.

Basic soil characteristics of the original experimental field were: texture (49.6 clay, 32.72 silt and 17.7% sand) was clay; pH, 6.43; electrical conductivity, 2.42 dSm^{-1}; OC, 4.08%; total N, 0.51%; available P, 65 mg kg^{-1} ;extractable K, 0.60 $cmol_c$ kg^{-1}; exchangeable Mg, 6.55 $cmol_c$ kg^{-1}; exchangeable Ca, 21.36 $cmol_c$ kg^{-1}; S, 6.3 mg kg^{-1}; cation exchange capacity, 35.6 meq/100; moisture, 13.14%; bulk density, 0.73; particle density, 2.98 and temperature, 9.5 °C.

Experimental treatments, design and procedure

The experiment was conducted in two factors randomized complete block design (fixed layout) with 16 treatments replicated 3 times. The factors were 4 levels each for N/P fertilizers (0/0, 46/23, 92/46 and 138/69 kg N/P ha^{-1}) and organic fertilizer sources (0/0, 5/5, 10/0 and 0/10 t FYM/LGM ha^{-1}). The plot size was 4 m x 4 m.

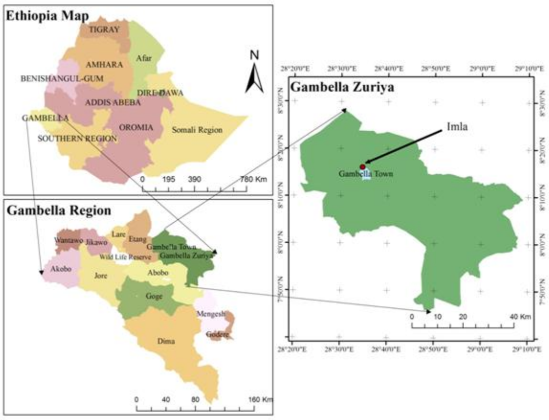

Fig. 1. Location map of the study area, Imla, nearby Gambella town in Gambella Zuria District.

Since germination percentage expresses the proportion of the total number of seed that are alive, it was determined through control test using news paper (absorbent material), water proof tray, randomly sampled mixed rice seed lot and pure water for 10 days before sowing on the field. Each day, the news paper was checked so that it remains moist and the number of germinated seeds was recorded. Germination (%) was calculated as the ratio of number of seeds germinated to number of seeds on the tray and recorded as 96.1% in the 2008 and 94.8% in the 2009.

The land preparation was started at the onset of the rainy season of 2008 and 2009. Land was plowed by a tractor in April 2008. Disking, harrowing and leveling were done to prepare a suitable seed bed to get proper germination and root development. As the experiment was conducted on a permanent layout, in order to avoid mixing up of the treatments, the land was prepared manually in 2009. The composition of organic amendments; FYM and LGM was as: OC 3.18 and 13.67%; pH 8.80 and 7.51; N 0.25 and 4.09%; P 1.22 and 2.09; K 13.55 and 43.91; S 0.09 and 2.80; Ca 5.74 and 3.36 and Mg 1.00 and 3.02 g kg^{-1}, respectively and were incorporated to the experimental plots 3 weeks before sowing.

Rice seeds (NERICA-3) were drilled by hand in rows 20 cm apart at a rate of 100 kg ha^{-1} in the last week of July and harvested in the third week of October each year. The two outer most rows and 0.5 m row length at both ends of each plot were considered as borders. The second, third and fourth rows on both sides of the plots were designated for destructive sampling, non destructive sampling and guard rows, respectively. Thus the net plot size harvested was 3.0 m x 2.4 m (7.2 m^2). Nitrogen fertilizer was applied in splits, ⅓ each at sowing, tillering and panicle initiation as urea, while whole P and a uniform dose of 20 kg K ha^{-1} in each plot were applied through triple super phosphate and potassium chloride at sowing, respectively. More than 50% of the seeds germinated within 6.0 days of sowing during both the years. The recommended agronomic practices were followed as and when required throughout the growing period of the crop.

Analysis of soil and plant samples

After removal of plant residues on the soil surface, representative soil samples (0-30 cm depth) were collected with soil auger from experimental area before plowing and from each plot after completion of each cropping cycle. Except soil cores used for bulk density (Db), soils, FYM and LGM samples were air-dried and ground to pass through a 2-mm sieve. The initial composited soil samples were analyzed for soil texture (hydrometer method; Jackson, 1973), cation exchange capacity (1 N ammonium acetate and distillation; Jackson, 1973), temperature, electric conductivity, soil moisture, bulk density and particle density following Sahlemedhin and Bekele (2000) soil analysis procedures. Further, the soils, FYM and LGM were analyzed for pH, organic carbon (OC) using wet digestion method (Walkely and Black, 1954), total N using the micro-Kjeldahl digestion (AOAC, 1994), available P using sodium bicarbonate solution (Olsen and Somers, 1982), extractable K, Ca and Mg using 1 M ammonium acetate solution (Rhoades, 1982) and recorded by atomic absorption spectrophotometer (Black, 1965) and sulphur (S) extracted with Ca (H_2PO_4) in 2NHOAc and measured turbid metrically (Hoeft *et al.*, 1973).

Statistical analysis

Data of each character were subjected to analysis of variance using SAS statistical software version 9.10 (SAS Institute Inc., 2003). Mean separation was done based on Duncan`s Multiple Range Test at 5% probability level.

Results and discussion

Effects of inorganic and organic fertilizers on soil properties

Soil pH

Soil pH was significantly affected only by cropping years, N/P ($P \leq 0.1$) and interaction of N/P and FYM/LGM ($P \leq 0.5$) while FYM/LGM, interactions of year by N/P, year by FYM/LGM, and year by N/P by FYM/LGM were not significant ($P > 0.05$) (Table 1). Higher soil pH (6.48) was recorded in 2008 than in 2009 which was 0.8% higher and 8.2% lower than the initial soil pH (6.43), respectively (Table 2). However, the soil pH decreased in all treatments over the initial value that might be due to a sever leaching loss of Ca^{++}, Mg^{++}, Na^{+}, K^{+}, etc. from the soil in comparison to Fe^{++}, Mn^{++}, H^{+} and others (Main, 1990).

Table 1. Combined analysis of variance showing the effects of rates of N/P and FYM/LGM application on soil OC, pH, soil and rice tissue N, P and K in 2008 and 2009.

Parameter	**Mean square for source of variation**							
	Y (1)	N/P(3)	M (3)	Y x N/P (3)	Y x M (3)	N/P x M (9)	Y x N/P x M (9)	Error (60)
				Soil				
pH 1:1 (H_2O)	7.889**	0.202**	0.069	0.030	0.031	0.100*	0.050	0.041
Organiccarbon (%)	50.084**	0.419	0.372	0.167	1.071	1.271	1.258	0.729
N (%)	0.150**	0.029*	0.059**	0.006	0.007	0.008	0.001	0.009
P (mg kg^{-1})	12060.167**	5571.750**	3431.694**	322.361	146.139	113.352	62.852	277.147
K (cmol$_c$ kg^{-1})	0.567**	0.008	0.268**	0.008	0.001	0.009	0.003	0.006
Mg (cmol$_c$ kg^{-1})	282.220**	1.580**	2.301**	0.304	0.447	0.941**	0.523*	0.238
Ca (cmol$_c$ kg^{-1})	449.887**	16.656**	76.879**	10.268**	36.118**	12.096**	15.368**	2.462
S (g kg^{-1} soil)	289.815**	185.152**	64.063**	75.602**	7.113	6.410	1.286	6.798
				Tissue				
N (%)	45.416**	2.390**	0.408	0.818**	0.051	0.080	0.283	0.149
P (g kg^{-1})	46.677**	0.073	1.303	0.592	0.357	1.073	1.337	0.675
K (g kg^{-1})	45.458**	5.926**	1.410	4.182**	1.117	0.285	0.141	0.736
S (g kg^{-1})	2.236**	0.215**	0.118	0.073	0.293**	0.097	0.094	0.052

Figures in parenthesis = Degrees of freedom; ** = Significant at P = 0.01; * = Significant at P = 0.05; M = FYM/LGM = Farm yard manure/*Leucaena*, *leucocephala* green manure; Y = Year

Table 2. The main effects of year, N/P and FYM/LGM application on pH, OC, N, P K and Mg of soil.

Treatment	**pH**	**OC (%)**	**N (%)**	**P (mg kg^{-1})**	**K (cmol$_c$ kg^{-1}**	**Mg (cmol$_c$kg^{-1})**	**Ca (cmol$_c$kg^{-1})**	**S (mg kg^{-1})**
Year								
2008	6.48a	1.39b	0.307b	109.83a	0.61a	8.70a	20.43a	12.38a
2009	5.90b	2.84a	0.386a	87.42b	0.46b	5.27b	16.10b	8.91b
			N/P (kg ha^{-1})					
0/0	6.29a	2.29	0.296b	80.63c	0.54	6.91b	19.41a	7.70b
46/23	6.20a	2.11	0.348ab	95.38b	0.51	7.37a	17.48b	8.91b
92/46	6.21a	2.09	0.367a	101.00b	0.52	6.87b	18.27b	12.44a
138/69	6.07b	1.98	0.374a	117.50a	0.56	6.80b	17.89b	13.52a
			FYM/LGM (t ha^{-1})					
0/0	6.12	2.07	0.272b	85.67c	0.41d	6.65b	16.31d	8.66c
5/5	6.23	2.00	0.374a	94.71bc	0.51c	6.80b	17.30c	10.06bc
10/0	6.19	2.11	0.365a	99.88b	0.56b	7.27a	19.17b	11.47ab
0/10	6.23	2.29	0.373a	114.25a	0.66a	7.24a	20.28a	12.39a
CV (%)	3.26	40.29	26.63	16.88	15.05	6.97	8.59	24.50

Means of the same factor in a column followed by the same letter are not significantly different at P > 0.05 by Duncan's Multiple Range Test. pH = The negative logarithm of the hydrogen ion activity of a soil [-log (H^+)]; OC = Organic carbon; FYM = Farmyard manure; LGM = *Leucaena leucocephala* green manure; M = Manures; CV = Coefficient of variation

Interaction of 0/0 kg N/P and 5/5 t FYM/LGM ha^{-1} obtained the highest soil pH (6.36) representing an increase of 9.2% than the lowest soil pH (5.76) but had no significant difference with other treatment combinations except with interactions of 92/46 kg N/P by 10/0 t FYM/LGM ha^{-1} and 138/69 kg N/P by 0/0 t FYM/LGM ha^{-1} (Table 3). Similar finding was reported by Hasan *et al.* (2009) and Sarwar *et al.* (2010). According to Oo *et al.* (2010), pH values among the different fertilizer treatments were not statistically significant. Soil pH was reduced under inorganic fertilizer by 2.07% and increased under organic manure by 1.6% than their control, which might be one of the evidences for better use of an organic fertilizer (Table 2). As indicated in 7.2.2, the FYM and LGM used were alkaline in nature with a pH of 8.8 and 7.51, respectively; and during microbial decomposition of incorporated organic manures, organic acid might have been released, which neutralized the alkalinity of the organic manures thereby leaving the pH of the soil almost what it was initially, that might be favourable for a good crop production (Okwuagwu *et al.,* 2003). Contrarily, Pattanayak *et al.* (2001) observed a decrease in soil pH after the use of organic materials. The production of organic acids (amino acid, glycine, cystein and humic acid) during mineralization (amminization and ammonification) of organic materials by heterotrophs and nitrification by autotrophs would have caused this decrease in soil pH.

Whalen *et al.*(2000) and Bodruzzaman *et al,*(2002) reported that cattle manure amended soil had significantly higher pH than not amended soil and the pH of Beaverlodge and Fort Vermillion soils increased from 4.8 to 6.0 and 5.5 to 6.3, respectively. Besides, Hasan *et al.* (2009) used N, NP, NK, NPK, NS, NZn, NSZn, NPKSZn and NFYM treatments and concluded that the soil pH was inconsistently decreased in all treatments over the initial value. On the other hand, Oo *et al.* (2010) reported that no significant difference for soil pH value among different inorganic and organic fertilizer treatments could be explained by the high buffering capacity of the soils.

Soil organic carbon

The effect of cropping year on soil OC was significant ($P \leq 0.01$) while N/P, FYM/LGM, interactions of year by N/P, year by FYM/LGM, N/P by FYM/LGM and year by N/P by FYM/LGM were not significant ($P > 0.05$) (Table 1). The soil attained higher OC (2.84%) in 2009 than that of 2008 (1.39%) probably due to the soil OM content initially declined according to the pattern typical for virgin soils brought under cultivation (Brady and Weil, 2002).

Although not significant, the N/P fertilizer and FYM/LGM levels showed a negative and positive effect on OC, respectively (Table 2). Soil OC declined substantially from initial (4.08%) by 65.9 and 30.4% in first and second year, respectively. Increasing N/P levels decreased soil OC than the control (Table 2).

Among the main effects of N/P and FYM/LGM levels, better OC content (2.29%) was recorded in control and 0/10 t FYM/LGM ha^{-1}. The decreased value of OC recorded with N/P rates was probably due to enhancement of the decomposition of soil OM with inorganic fertilizers which led to degradation of soil structure and nutrient mineralization, thereby more availability for plant uptake, though there might also be leaching losses (Chen, 2006). Whereas, OC increased in the 10/0 and 0/10 t FYM/LGM ha^{-1} were attributed to direct incorporation of the organic matter in the soil. Titilola (2006) reported that the level of OC decreased by 59% under inorganic fertilizer due to stimulated decomposition of soil OM by the applied fertilizer which led to higher N mineralization. The inorganic combination of 120/26/33 kg N/P/K ha^{-1} had no significant effect on OC content in soil after first year, whereas after the second year the combinations significantly increased OC content in soil over the control.

The organic combination of green manure (GM) + 20 kg N ha^{-1} + biofetilizers had no significant effect on OC content in soil after first year, whereas after the second year the combinations significantly increased OC content in soil over the control (Sharma *et al.*, 2008). They added that organic combination of GM + 20 kg N ha^{-1} + combinations of higher rates of organic nutrition were significantly superior to inorganic nutrition after the three years.

The OC content in soil increased in proportion with the amount of OC added through an organic combination of GM + 80 kg N ha^{-1} + biofertilizers adding about 16 t OC ha^{-1} $year^{-1}$. The content of OC was decreased by 17, 44 and 47% under organic fertilizer, inorganic + organic fertilizer and no fertilizer, respectively (Titilola, 2006). Whereas, the

Table 3. Interaction effects of N/P and FYM/LGM application on soil pH content.

N/P (kg ha^{-1})	FYM/LGM (t ha^{-1})			
	0/0	5/5	10/0	0/10
0/0	6.15ab	6.36a	6.34ab	6.31ab
46/23	6.27ab	6.20ab	6.15ab	6.17ab
92/46	6.29ab	6.18ab	6.11b	6.25ab
138/69	5.76c	6.18ab	6.14ab	6.20ab

Means of the same factor in a row or a column followed by the same letter are not significantly different at P > 0.05 by Duncan's Multiple Range Test. FYM = Farmyard manure; LGM = *Leucaena leucocephala* green manure

Table 4. Interaction effects of cropping year, N/P and FYM/LGM on soil Mg content of rice field.

N/P (kg ha^{-1})	**2008**				**2009**			
	FYM/LGM (t ha^{-1})				FYM/LGM (t ha^{-1})			
	0/0	5/5	10/0	0/10	0/0	5/5	10/0	0/10
	Soil Mg (cmol$_c$ kg^{-1})							
0/0	8.95a-e	8.66c-f	8.56d-g	8.11efg	4.86hi	5.51h	5.80h	4.85hi
46/23	9.21a-d	8.08efg	9.79ab	9.82a	5.36h	5.64h	5.44h	5.60h
92/46	7.88fg	8.38d-g	8.96a-e	8.65c-f	4.89hi	4.85hi	5.65h	5.69h
138/69	7.70g	8.10efg	8.91b-e	9.49abc	4.38i	5.15hi	5.02hi	5.68h

Means of the same factor in a row or a column followed by the same letter are not significantly different at P > 0.05 by Duncan's Multiple Range Test. FYM = Farmyard manure; LGM = *Leucaena leucocephala* green manure

Table 5. Interaction effects of cropping year, N/P and FYM/LGM on soil Ca content of rice field

N/P (kg ha^{-1})	**2008**				**2009**			
	FYM/LGM (t ha^{-1})				FYM/LGM (t ha^{-1})			
	0/0	5/5	10/0	0/10	0/0	5/5	10/0	0/10
	Soil Mg (cmol$_c$ kg^{-1})							
0/0	23.50b	19.51def	23.21bc	21.18bcd	15.64hij	17.66f-i	16.33g-j	18.28e-h
46/23	14.25j	17.78e-i	19.27d-g	23.37b	16.55f-j	16.45g-j	16.07hij	16.08hij
92/46	17.17f-j	20.54cde	21.33bcd	23.89b	14.80ij	15.24hij	17.13f-j	16.08hij
138/69	14.28i	16.72f-j	23.61b	27.23a	14.28j	14.49j	14.38j	16.09hij

Means of the same factor in a row or a column followed by the same letter are not significantly different at P > 0.05 by Duncan's Multiple Range Test. FYM = Farmyard manure; LGM = *Leucaena leucocephala* green manure

Table 6. The main effects of year, N/P and FYM/LGM application on N, P, K and S contents of rice tissue

Treatment	**N (%)**	**P (g kg^{-1})**	**K (g kg^{-1})**	**S (g kg^{-1})**
Year				
2008	1.06b	1.16b	4.67a	0.93b
2009	2.43a	2.56	3.30b	1.24a
		N/P (kg ha^{-1})		
0/0	1.40b	1.81	3.44b	0.96b
46/23	1.58b	1.93	3.96b	1.07ab
92/46	1.91a	1.88	4.65a	1.13a
138/69	2.10a	1.82	3.89b	1.18a
		FYM/LGM (t ha^{-1})		
0/0	1.59	1.55	3.65	1.03
5/5	1.74	1.88	4.02	1.18
10/0	1.75	1.89	4.22	1.10
0/10	1.91	2.11	4.05	1.04
CV (%)	22.11	44.19	21.53	20.87

Means of the same factor in a column followed by the same letter are not significantly different at P > 0.05 by Duncan's Multiple Range Test. FYM = Farmyard manure; LGM = *Leucaena leucocephala* green manure; M = Manures; CV = Coefficient of variation

Table 7. Interaction effects of cropping year by N/P on soil S, tissue N and K and year by FYM/LGM on tissue S contents.

N/P (kg ha^{-1})	**Soil sulfur (mg kg^{-1} soil)**		**Rice tissue**						
			N (%)		K (g kg^{-1})		FYM/LGM (t ha^{-1})	S (g kg^{-1})	
	2008	2009	2008	2009	2008	2009		2008	2009
0/0	7.47c	7.94c	0.90e	1.90c	4.02b	2.86c	0/0	0.82e	1.24b
46/23	9.64bc	8.14c	0.81e	2.36b	4.66ab	3.26c	5/5	0.90de	1.46a
92/46	15.87a	9.00bc	1.00e	2.81a	4.88a	4.41ab	10/0	1.02cde	1.17bc
138/69	16.55a	10.50b	1.52d	2.67ab	5.13a	2.65c	0/10	0.99cde	1.08bcd

Means of the same factor in a row or a column followed by the same letter are not significantly different at $P > 0.05$ by Duncan's Multiple Range Test. FYM = Farmyard manure; LGM = *Leucaena leucocephala* green manure

OM content of soil was found highest in treatments receiving 100% N from FYM or 75% N from FYM and 25% from urea (Shah and Ahmad, 2006). Soil OM content was significantly higher in combined use of FYM and inorganic fertilizers application.

Comparing FYM, *Sasbania aculeate* and fertilizer application in a rice-wheat rotation on a Typic ustifluvent, Chettri *et al.*(2003) found that the application of 7 t FYM ha^{-1} to both the rice and the wheat crops over eight years increased OC levels from 1.4 to 1.6%, but had no effect on yield of either crops. Singh *et al.* (2001) also reported that the OC content of the soil decreased considerably at control (no NPK) and 50/20/10 kg NPK ha^{-1} alone as well as in combination with FYM or blue green algae (BGA), or FYM + BGA, from its initial value after completion of 4 cycles of a rice-wheat cropping system. Singh *et al.* (2001) also found that the OC content of soil increased in the 75/30/15 N/P/K kg ha^{-1} either alone or in combination with FYM and/or BGA, whereas maximum value of OC was recorded in the treatment 100/40/20 NPK kg^{-1} (49.1% increase over initial).

Application of FYM together with inorganic fertilizers significantly increase soil OM and CEC (Oo *et al.*, 2010). This increase was probably due to enhanced root growth leading to accumulation of more organic residues in the soil. Soil OM is not only a pool of plant nutrient but also affects soil physical, chemical and biological properties and plays a key role in establishing and maintaining of the soil fertility (Haefele *et al.*, 2004; Fageria, 2009). Therefore, OM applications endorsed the increase in OC of soil (Myint *et al.* 2010).

Soil nitrogen

The effects of cropping year, FYM/LGM ($P \le 0.01$) and N/P ($P \le 0.05$) on the soil total N were significant; whereas, interactions of year by N/P, year by FYM/LGM, N/P by FYM/LGM and year by N/P by FYM/LGM were not significant ($P > 0.05$) (Table 1). The N content in the soil declined after the crop harvest compared to that observed before sowing of rice (0.51%). The low values of total N could be as a result of crop uptake, immobilisation by microorganisms and nitrogen loss through volatilisation and leaching (Defoer *et al,* 2004). However, soil N value improved significantly over 2008 after the harvest in 2009 (Table 2). Increasing application of N/P rates linearly and significantly increased the content of soil N that might be due to its application as readily available form and climatic conditions (Sarwar *et al.*, 2009). Consequently, the highest soil N content was obtained with 138/69 kg N/P ha^{-1} over the control but had no significant variation with other N/P rates and accounted for an increase of 20.9% over the control (Table 2).

The application of FYM/LGM also showed significant ($P \le 0.05$) effect on soil N content and the maximum (0.374%) was recorded with 5/5 t FYM/LGM ha^{-1} but had no significant difference with 10/0 and 0/10 t FYM/LGM ha^{-1} and accounted for an increase of 27.3% over the control (Table 2). Although soil N content increased with application of N/P and FYM/LGM over the control, still it was depleted over the initial (0.51%) soil N value.

Reduction was more in the first (37.8%) than the second (22.4%) season compared to the initial soil N content. Janzen and Schaalji (1992) found that fertilizer N losses were twice as large as when GM plus fertilizer was applied to barley. Their interpretation was that GM promoted high levels of nitrate and available carbon in the soil, enhancing de-nitrification (Shah and Ahmad, 2006).

Titilola (2006) found that soil N value decreased in all plots after cropping, but more under inorganic fertilizer alone because nutrients from this source were readily available compared to that from organic source. On the other hand, reduction in soil N content was less under inorganic + organic fertilizers than inorganic fertilizer alone indicating N was conserved under combined application of fertilizers (Chettri *et al.* 2003; Myint *et al.*, 2010; Oo *et al.*, 2010). Further, Regmi *et al.* (2002) and Shah and Ahmad (2006) also reported that soil N content was highest in treatment receiving 100% N from FYM or 75% from FYM and 25% from urea. Production of appreciable quantities of carbonic acids during decomposition of OM, mineralize the complex organic substances, which in turn would contribute to N pool (Vasundhara, 2006), thus, N balance was maintained for a long time under FYM among the all used organic treatments (Linquist *et al.*, 2007). This might be a reason for rice yield and N availability of low fertility soil increased within three years of continuous organic manure application. However, it may depend on the kind and amount of OM used (Myint *et al.* 2009).

Similarly, Shah *et al.* (2006) reported that fertilizer N losses were twice as large as when GM plus fertilizer was applied due to GM promoted high levels of nitrate and available carbon in the soil, enhancing denitrification. Xu *et al.* (1993) found large losses of 25 to 41% of N added from *Leucaena* prunings. On the other side, Sharma *et al.* (2008) found no significant differences between different organic combinations in all the experimental years. Suzuki (1997) stated that organic materials with a high C/N ratio are likely to compete with crops for N, which can lead to N deficiency in extreme cases. Moreover, urea N applied in inorganic nutrition might have lost through leaching and denitrification as reported by Prasad and Power (1995). Further, Yadav *et al.* (1998) was reported a reduction in N content in soil in unfertilized plots of rice-wheat cropping system. Likewise, the total N content in soil decreased over its initial level by 50 mg kg^{-1} soil in the control plots (Sharma *et al.*, 2008).

Chettri *et al.* (2003) reported that from the third year, green manuring (*Sasbania aculeate*) was able to replace the effect of the recommended N fertilizer in increasing soil total N value and rice yield by reducing base saturation. Sharma *et al.* (2008) identified that the increase in total N content in soil after three cycles of rice-wheat cropping system over initial level was least (15 mg kg^{-1} soil) with inorganic nutrition and highest (45 mg kg^{-1} soil) with an organic combination of GM + 80 kg N ha^{-1} as FYM + biofertilizers. However, Singh *et al.* (2001) found that the highest soil N value (24.1%) registered in the treatment 100/40/20 kg NPK ha^{-1} was higher than initial value. Sharma *et al.* (2008) reported that the inorganic combination was at par with lowest rate of organic combination after the first two years but significantly inferior to this combination after the third year, which clearly indicated mineralization of organic nitrogen takes place slowly and thus organic N can be retained in soil for longer period. Hence, application of FYM together with inorganic fertilizers significantly increased soil OM slowly, which intern increased the availability of soil N value (Oo *et al.*, 2010).

Soil available phosphorus

The significant differences on soil P recorded due to year, N/P and FYM/LGM ($P \leq 0.01$) while interactions of year by N/P, year by FYM/LGM, N/P by FYM/LGM and year by N/P by FYM/LGM were not significant ($P > 0.05$) (Table 1). More soil P content (109.83 mg) was recorded in 2008 as compared to 2009 most probably due to favorable soil pH and climatic conditions recorded in 2008 (Table 2). The favorable pH and climatic conditions might have enhanced the solubility of P in the soil (Sarwar *et al.*, 2009). After the first year, there was an increase of 69.2% over the initial available P content (65 mg kg^{-1} soil), but after the second cropping year it declined, but increased by 33.8 and 31.1% compared to soil P contents obtained after the first crop year and initial soil, respectively (Table 2).

Soil P value increased with the increase in application of N/P rates up to 138/69 kg N/P ha^{-1} (Table 2). Consequently, the maximum soil P value (117.50 mg kg^{-1} soil) was found with the application of 138/69 kg N/P ha^{-1} (representing an increase of 31.4% compared to the control) which was significantly higher over the other N/P treatments. The highest available P value was recorded in the treatment NPK which was followed with treatment of NP due to P from inorganic source was readily available (Hasan *et al.*, 2009; Sarwar *et al.,* 2010).

Moreover, application of FYM/LGM positively influenced soil P value than the lowest soil P content obtained from the control; whereas, the significantly higher soil P value was observed with 0/10 t FYM/LGM ha^{-1} over the other treatments (Table 2) which showed an increase of 24.6% over the control (Table 2). This increase might be attributed to green biomass addition and improvement in the soil physical and chemical properties in the root zone (Narayan and Lal, 2006). Available P in the treated plots was very high as a result of residual effect (Okwuagwu *et al.,* 2003). Mineralization (an increase in available P content) and immobilization of P in soil with the addition of organic source (FYM, GM, poultry manure, etc) alone or in combination with inorganic fertilizers have been reported by Vasundhara (2006). When an organic source of nutrition is applied,the bond of phosphorus compounds with $CaCO_3$ is broken, resultantly, phosphorus is kept at higher amounts of available form (Sarwar *et al.*, 2008).

The analysis of chemical properties of FYM and LGM before used for the experiment also showed highest P value in LGM (2.09%). Chettri *et al.*(2003) reported that P application through FYM was not adequate for rice, whilst an application of 34 kg P ha^{-1} to the rotation gave an economic yield increase only in rice and then only in the first four years of the experiment. Whereas, Singh *et al.* (2007) observed that the incorporation of manure and crop residues has been shown to increase the amount of soluble OM that are mainly organic acids that increased the rate of desorption of phosphate and thus improved the available P content in the soil. Use of the combination of FYM and inorganic fertilizers, gave the highest soil extractable P among the different fertilizer treatments (Oo *et al.*, 2010). Linquist *et al.* (2007) also reported that P balance was maintained for a long time under FYM among all the used organic treatments.

Singh *et al.* (1998) also reported that the soil available P was improved appreciably with application of either FYM or GM. Singh *et al.* (2001) found highest P value with 100/40/20 kg NPK + FYM + BGA which was increased by 69.2% than initial. The results obtained by Singh *et al.* (2007), also showed available P value found to be significantly increased due to organic farming practice over control as well as chemical fertilizer application. However, Hasan *et al.* (2009) added that soils treated with P fertilizers contained higher amount of available P compared to other treatments. While Oo *et al.* (2010) reported the applications of FYM together with inorganic fertilizers significantly increased soil OM and CEC, then availability of P. Moreover, Chettri *et al.* (2003) stated that from the third year, green manuring was able to replace the effect of the recommended P fertilizer application in increasing rice yield.

Soil exchangeable potassium

The soil exchangeable K significantly ($P \leq 0.01$) varied with the effects of year and FYM/LGM while N/P, interactions of year by N/P, year by FYM/LGM, N/P by FYM/LGM and year by N/P by FYM/LGM were not significant ($P > 0.05$) (Table 1). The soil exchangeable K was more (0.61 $cmol_c$ kg^{-1} soil) in 2008 than in 2009 (0.46 $cmol_c$ kg^{-1} soil) that might be due to favorable climatic conditions (Fig. 7.2) and soil pH during 2008 cropping year that enhanced the solubility and release of soil K from the fixed pole. Increasing application rates of N/P from control to 138/69 kg ha^{-1} didn`t show significant variation among the soil exchangeable K probably due to congenial conditions for availability of K during rainy season and better utilization of its reserve quantity by rice plant.

The main effects of N/P levels were negatively but not significantly influenced the soil K over the initial (0.60 cmol$_c$ kg^{-1} soil) value that had no significant reduction over control (Table 2). Kaur and Benipal (2006) also reported that plots receiving N/P showed no marked reduction in water soluble K as compared to control. In second season, soil K value declined more than in the first season. Singh *et al.* (2004) also reported that the available pool of K in the soil showed a declining trend with continuous rice-wheat cropping in the urea treatment. Kaur and Benipal (2006) however, found that NPK application markedly increased the contents of water soluble K and during decomposition of OM, significant amount of K was released.

The application of FYM and LGM either alone or in combination significantly enhanced soluble K content of soil over control. Similarly, Narayan and Lal (2006) observed increased soil available K content with the application of green manuring over no green manured plots. Significantly higher soil exchangeable K obtained with application of 0/10 t FYM/LGM ha^{-1} (37.9% over the control) compared to the other treatments. The lowest soil exchangeable K (0.41 cmol$_c$ kg^{-1} soil) was recorded from control plots. However, Sarwar *et al.* (2010) observed no significant soil K value under organic manure treatments. Due to erratic rainfall and high temperature (Fig. 7.2) the availability of K was restricted. On the other hand, Mathur (1997) observed that application of recommended FYM significantly increased the available K over 50% FYM + 50% NPK.

The increase in available K in soils of organic farms could be attributed to the direct addition of K to the available pool of the soil from organic manures applied to soil which enhanced reduction of K sorption (Vasundhara, 2006). Singh *et al.* (2001) also reported that use of FYM with fertilizer N increased the available K status of the soil. Moreover, Oo *et al.* (2010) reported that the highest value of exchangeable K in soil was recorded in the plots with the combination of FYM and inorganic fertilizers. According to Linquist *et al.* (2007), K balance was maintained for a long time under FYM among the all used organic treatments.

In contrast, Hasan *et al.* (2009) found that integrated use of inorganic and organic fertilizers significantly decreased the soil exchangeable K value by 50% over the initial level during the last 29 years. According to Main and Moslehuddin (1999), a nutrient balance study indicated a severe loss of K each year due to weathering of soil material. In addition, Main (1991) recorded sever K reduction and reported that NH_4^+ formed due to hydrolysis of urea displaced K from exchange sites that decreased K content. Moreover, the decrease in K content over the initial status might be the effect of leaching loss of K from the experimental field in addition to crop uptake (Hasan *et al.*, 2009) and smaller application through fertilizer source (Singh *et al.*, 2001). However, applications of FYM together with inorganic fertilizers significantly increased soil OM, CEC, and availability of K (Oo *et al.*, 2010). Likewise, green manuring (*Sasbania aculeate*) increased soil available K levels and reduced base saturation (Chettri *et al.*, 2003).

Soil exchangeable magnesium

The soil Mg content (Table 1) significantly varied by the effects of year, N/P, FYM/LGM, interaction of N/P by FYM/LGM ($P \leq 0.01$) and year by N/P by FYM/LGM ($P \leq 0.05$) while interactions of year by N/P and year by FYM/LGM was not significant ($P > 0.05$). Soil Mg was higher in 2008 than in the 2009 which might have resulted due to weather conditions as well as cropping variation between the two years

(Fig. 7.2) that maintained better equilibrium of soil nutrients as well as applied N/P and FYM/LGM.

Exchangeable Mg content of the post harvest soil was significantly affected by interaction of N/P and FYM/LGM in both 2008 and 2009 years (Table 4). So, the highest value (9.82 cmol_c kg^{-1} soil) was obtained with interaction of 46/23 kg N/P + 0/10 t FYM/LGM ha^{-1} that had no significant variation with interactions of 46/23 +0/0, 46/23 + 10/0, 92/46 + 10/0 and 138/69 kg N/P + 0/10 t FYM/LGM and control in the same year. The lowest soil Mg content was obtained from the interaction of 138/69 kg + 0/0 t FYM/LGM ha^{-1} in 2009 which decreased soil Mg content by 55.4% compared to the highest soil Mg value. Sarwar *et al.* (2008) reported that organic matter, N, P and K contents of soil significantly enhanced due to organic matter added alone or along with chemical fertilizer. The exchange reactions enhanced due to the release of H$^+$ from the decomposition of organic materials resulted in more availability of Mg for plants. The values of Mg were 1037.8 ppm in 100% FYM, 767.0 ppm in 12.5% FYM and 685.4 ppm in 100% top soil (Mgbeze and Abu, 2010). Magnesium was within the normal range in control, N, NP, NK, NPK and FYM treatments, with the highest concentration in the NP and FYM, which were slightly above the critical toxic level (Regmi *et al.*, 2002).

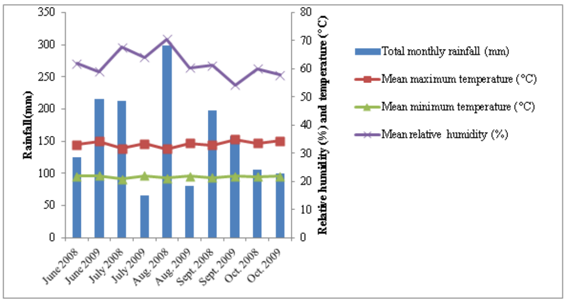

Fig. 2. Monthly weather data for the 2008 and 2009 cropping seasons (Source: Gambella Meteorological Service Branch Office);

Soil exchangeable calcium

The Ca content of soil (Table 1) varied significantly by the effects of year, N/P, FYM/LGM, interactions of year by N/P, year by FYM/LGM, N/P by FYM/LGM and year by N/P by FYM/LGM ($P \leq 0.01$). Soil Ca content was higher in 2008 than in the 2009 (Table 2) which might be due to environmental variation between the two years (Fig. 2) that maintained better equilibrium of soil nutrients as well as applied N/P and FYM/LGM.

The 2008 and 2009 treatment combination (Table 5) showed significant variation on soil Ca content due to the interaction effect of N/P and FYM/LGM. Consequently, the highest value of soil Ca (27.23 cmol_c kg^{-1}) was obtained with interaction of 138/69 kg N/P + 0/10 t FYM/LGM ha^{-1} over the other treatment combinations. Okwuagwu *et al.* (2003) also found that Ca content of the soil increased after manuring which resulted from the decomposition of organic fertiliser. Exchangeable Ca increased with application of treatments but it was significant in poultry manure application treatment while synthetic fertilizer also raised this concentration but it was not significant as compared to poultry manure treatments (Sarwar *et al.*, 2008). Calcium was within the optimum range in control, N, NP, NK, NPK and FYM treatments (Regmi *et al,* 2002). Rao and Srivastava (2001) reported that readily available organic sources such as FYM offer a potential additional 15 metric tons of NPK year^{-1}.

Soil sulfur

The cropping year, N/P, FYM/LGM and interaction of year by N/P had significant ($P \leq 0.01$) effect on soil S, but the interaction effects of year by FYM/LGM, N/P by FYM/LGM and year by N/P by FYM/LGM were not significant ($P > 0.05$) (Table 1). The soil S content was more in 2008 than that in 2009 (Table 2).

The over year treatment combination effect of N/P on soil S was significant ($P \leq 0.01$) both in 2008 and 2009 cropping years (Table 7). So, the highest soil S (16.55 mg kg^{-1}) was obtained with 138/69 kg ha^{-1} in 2008 over the other treatment combination but it had no significant variation with 92/46 in the same year. Similar report was given by Hasan *et al.* (2009) who found that highest soil S value (18.28 mg kg^{-1}) in treatment NPKSZn. Response of soil S obtained with the control and 46/23 kg N/P ha^{-1} had no significant ($P > 0.05$) difference during the two cropping years. Soil S recorded with control was found to be the lowest over the other treatment combination in both experimental years.

In addition, effects of FYM/LGM on soil S value were significant ($P \leq 0.01$) (Table 2). Therefore, the highest soil S value was obtained with 0/10 t FYM/LGM ha^{-1} that had no significant difference with 10/0 t FYM/LGM ha^{-1}. Soil S content recorded with control was found to be lowest over other FYM/LGM treatments except 5/5 t FYM/LGM. The results were in agreement with the findings of Vasundhara (2006) who noticed higher value of available S in the soils under organic farming than soils under conventional farming. However, Prasad and Sinha (2000) also reported that available S increased significantly in soil when different levels of fertilizers were applied along with crop residues and organic manure.

Effects of inorganic and organic fertilizers on rice tissue

Tissue nitrogen

The rice tissue N had significant variation with cropping year, N/P and interaction of year by N/P ($P \leq 0.01$) while, FYM/LGM, interactions of year by FYM/LGM, N/P by FYM/LGM and year by N/P by FYM/LGM had no significant (Table 1). More tissue N content (2.43%) was recorded in 2009 over 2008 (Table 6) that might be due to monthly mean air temperature (28.03^{o}C), precipitation (123.7 mm) and relative humidity (59.12%) in 2009 provided favorable environment for more availability of soil N content (0.38%) for better nourishment of the rice plant over the mean air temperature (26.98 ^{o}C), precipitation (188.26 mm) and relative humidity (64.39%) in 2008.

The effect of N/P on tissue N was significant ($P \leq 0.01$) both in 2008 and 2009 cropping seasons (Table 7). Consequently, the highest tissue N (2.81% kg^{-1}) was obtained with 92/46 kg ha^{-1} in 2009 over the other treatment combination except with 138/69 kg ha^{-1} in the same year. Applied N/P to soil in the form of readily available might have be increased soil N and enhanced rice plant uptake of N that raised tissue N content. Tissue N content recorded with 46/23 kg N/P ha^{-1} was found to be lowest in 2008 which had no significant difference with control and 92/46 kg N/P ha^{-1} in the same year over the other treatment combination.

Abid *et al.* (2002) noted significantly maximum N value (10.4%) in treatment 150/200/60 kg NPK ha^{-1} in silty clay loam soil whereas minimum was found in control plots (0.3%) of wheat tissue. The increase in N content of tissue might be due to the reason that the P application had improved the root growth and other physical properties of the soils, due to which N availability to plant was increased. Low N value in rice tissue in the case of 46/23 kg N/P ha^{-1} was probably associated with poor growth of the plant. According to Myint *et al.* (2010), understanding of nutrient removal by a crop may provide the important information for the soil fertility management by comparing the plant total accumulation to application from all sources.

In low level applications (e.g., application of 40 kg N ha^{-1} in cow manure, poultry manure, straw + urea and urea), plant accumulations were higher than applied amount, suggesting that the N amount from application was lower than crop needs. Consecutively, it may lead to decline in soil fertility in succeeding season due to inadequate nutrition. Dobermann *et al.* (1998) stated that the demand of the rice plant for other macronutrients mainly depends on the N supply. In the same way, higher plant macronutrient accumulation was observed at higher N level in all treatments of our study.

Tissue phosphorus

Analysis of variance (Table 1) showed significant ($P \leq 0.01$) differences in tissue P content only during the cropping years; whereas the main and interactions of fertilizers on tissue P content were not significant ($P > 0.05$) probably due to congenial conditions for availability of P during rainy season and a better utilization of reserve quantity of soil P by rice in slightly acidic soil pH (Table 3). The tissue P content (Table 6) was more (2.56 g kg^{-1} tissue) in 2009 than in 2008 (1.16 g kg^{-1} tissue) probably due to the climatic variation between the growing seasons (Fig.7.2). However, Abid *et al.* (2002) found significant influence on wheat straw P value with P levels over control. Myint *et al.* (2010) also reported that tissue P value was significantly influenced with cow manure, poultry manure, urea, M-coat and rice straw + urea mix application at the rate of 40 and 80 kg N ha^{-1}.

Though not significant, the highest tissue P value (1.93 g kg^{-1}) was obtained with 46/23 kg N/P ha^{-1} while the lowest P value (1.81 g kg^{-1}) was observed in control plots (Table 6). However, Abid *et al.* (2002) recorded the maximum P value (0.65%) with 200/150/60 kg NPK ha^{-1} and minimum (0.20%) was in control. As well, Dobermann *et al.* (1998) found higher plant P content with higher N level in all treatments of their study.

Though not significant, the highest tissue P value (2.11 g kg^{-1}) was recorded with 0/10 t FYM/LGM ha^{-1} while the lowest P value (1.54 g kg^{-1}) observed with control plots. According to Regmi *et al.* (2002), the P pools significantly increased with time in the NPK and FYM treatments but remained unchanged in the control. In FYM, the total and available pools increased at the rates of 20.1 and 6.4 mg kg^{-1} year^{-1}, respectively. In year 19th, 57 and 30% of total Bray P were recorded with NPK and FYM, respectively. Input of P through FYM exceeded P output through crop removal, resulting in a large build up of P.

Tissue potassium

The rice tissue K had significant variation with effects of year, N/P, interaction of year by N/P ($P \leq 0.01$) and FYM/LGM ($P \leq 0.05$ while interactions of year by FYM/LGM, N/P by FYM/LGM and year by N/P by FYM/LGM were not significant (Table 1). More rice tissue K (4.67 g kg^{-1}) was recorded in 2008 over 2009 (Table 6) that might be due to the meteorological variation between the cropping years.

The interaction effect of cropping years and N/P combination on rice tissue K was significant ($P \leq 0.01$) of which the highest rice tissue K (5.13 g kg^{-1}) was obtained with 138/69 kg ha^{-1} in 2008, representing an increase of 44.3% over the lowest tissue K, but had no significant variation with 46/23 kg N/P ha^{-1} in the same year and 92/46 kg N/P ha^{-1} in the both years (Table 7).

Although not significantly affected, the highest tissue K value (4.22 g kg^{-1}) was recorded in the treatment 10/0 t FYM/LGM ha^{-1} while the lowest K value (3.65 g kg^{-1}) observed with control plots. Sarwar *et al.* (2008) showed that when the acid or acid forming compounds are added in the form of compost to the soil, these affect potassium availability. The effect is positive resulting in more availability of K to the plants. The hydrogen ions released from organic materials are exchanged with K on exchange site or set free from the fixed site of the clay micelle. Thus, the overall status of soil regarding availability of potassium content is improved. Regmi *et al.* (2002), observed K noticeably below the critical level of deficiency in all the treatments (control, 100 N, 100/13 NP, 100/25 NK, 100/13/25 kg NPK ha^{-1} and 80/18/40 NPK/FYM) with a very low concentration in the FYM treatment. They also reported that the average annual decline of total K was 0.18 and 0.09 g kg^{-1} in the NPK and FYM treatments, respectively. This suggests that the application of 25 and 40 kg K ha^{-1} per crop in the NPK and FYM treatments, respectively, was not sufficient to maintain the soil K level in the rice-rice-wheat rotation. Myint *et al.* (2010) reported that K was significantly different with cow manure, poultry manure, urea, M-coat and rice straw + urea mix application at the rate of 40 and 80 kg N ha^{-1}.

Tissue sulfur

Cropping year, N/P and interaction of year by FYM/LGM had significant ($P \leq 0.01$) effect on S content of rice tissue, but the effects of FYM/LGM, interactions of year by N/P, N/P by FYM/LGM and year by N/P by FYM/LGM were not significant

(Table 1). The S content was more in 2009 than that of 2008 (Table 6).

Increasing N/P rates from control to 138/69 kg N/P ha^{-1} significantly increased the rice tissue content of S (Table 6). As a result, the highest tissue S (1.18 g kg^{-1}) was obtained with the application of 138/69 kg N/P ha^{-1} but had no significant variation with the other treatments except the control.

Effect of organic manures (FYM/LGM) over year combination on rice tissue S content was significant ($P \leq 0.01$) in 2009 while it was not significant in 2008 (Table 7). Consequently, the highest rice tissue S content (1.46 g kg^{-1}) was obtained with 5/5 t FYM/LGM ha^{-1}. In most plants it makes up 0.2 to 0.3 (0.05 to 0.5) percent of dry matter (FAO, 2000). Rice tissue S content recorded with control was found to be lowest that had no significant variation with 5/5, 10/0 and 0/10 t FYM/LGM ha^{-1} in 2008.

However, Reddy (2006) reported that rice tissue S content was lower while NP levels were higher. So, the N:S ratio has been proposed to better express the S status in the plants than total S alone. Thus, critical N:S ratio for maximum dry weight found to be 22 at panicle initiation. Reddy (2006) also found its variation from 23 at tillering to 13 at maturity while Bell and Kover (2009) recorded 17 at panicle initiation. Generally, Bell and Kover (2009) reported that sufficiency ranges of rice tissue N, P, K, Mg, Ca and S are 30-34, 1.8-2.9, 15-27, 1.9-3.9, 1.5-3.9 and above 1.5 g , respectively at panicle initiation. Integrated supply of plant nutrients through FYM and NPK, along with *Sesbania* green manure, played a significant role in sustaining soil fertility and crop productivity (Chen, 2006).

Conclusion

From the experimental results there were clear indications that the combined use of N/P with FYM/LGM showed better performance after 2 years than sole N/P or FYM/LGM to sustain the soil properties and rice tissue nutrient contents. Therefore, this can be used to substitute chemical NPK fertilizers to improve the overall fertility by releasing nutrients, reduce the environmental pollution and increase the output of the land that enable to achieve sustained rice productivity. Hence, there could be gradual reduction of FYM/LGM in future applications. Annual soil testing of nutrients will help to establish appropriate rates of FYM/LGM additions.

Acknowledgement

The authors are thankful to the Gambella Agricultural Research Institute/Gambella Peoples National Regional State/Ethiopian Institute of Agricultural Research Rural Capacity Building Project and National Soil Research Center for financial and fertilizer support, respectively, to carry out the field and laboratory studies.

References

Abid M., Ahmad F, Ahmad N, Ahmad I. 2002. Effect of phosphorus on growth, yield and mineral composition of wheat in different textured saline-sodic soils. Asian Journal of Plant Sciences **1(4)**, 472-475.

Antil RS, Singh M. 2007. Effects of organic maures and fertilizers on organic matter and nutrients status of the soil. Journal of Agronomy and Soil Science **53**, 519-528.

AOAC (Association of Official Analytical Chemist).1994. Official method of analysis. 12th Ed. Washington, DC.

Bell PF, Kovar JL. 2009. Rice. pp. 25-28. In: Campbell, C. R. (ed.). Reference sufficiency ranges for plant analysis in the southern region of the United States. Southern Cooperative Series Bulletin No. **394**.

Black CA. 1965. Methods of soil analysis. Part 2: Chemical and microbiological properties. Inc. Madison, Wisconsin, American Society of Agronomy **9**, 1572.

Bodruzzaman M, Sadat MA, Meisner CA, Hosain ABS, Khan HH. 2002. Direct and residual effects of applied organic manures on yield in wheat-rice cropping pattern. Symposium No. 05, Paper No. 781, Wheat Res. Centre, BARI, Bangladesh.

Buresh RJ, Witt C. 2008. Balancing fertilizer use and profit in Asia's irrigated rice systems. Better Crops **92**, 18-22.

Chen JH. 2006. The combined use of chemical and organic fertilizers and/or biofertilizer for crop growth and soil fertility. International Workshop on Sustained Management of the Soil-Rhizosphere System for Efficient Crop Production and Fertilizer Use, 16-20 October 2006, Land Development Department, Bangkok, Thailand.

Chettri GB, Ghimiray M, Floyed CN. 2003. Effects of farm yard manure, fertilizers and green manuring in rice-wheat systems in Bhutan: Results from A long-term experiment. Cambridge Journal **39(2)**, 129-144.

Defoer T, Macros CSW, Monty PJ, Frederic L, Olaf E, Robert GG. 2004. Challenges and technical opportunities for rice-based production systems for food security and poverty alleviation in Sub-Saharan Africa., FAO Rice Conference 12-13 February 2004, Rome, Italy.

Dobermann A, Cassman KG, Mamaril CP, Sheehy SE. 1998. Management of phosphorus, potassium, and sulfur in intensive, irrigated lowland rice. Field Crops Research **56**, 113-138.

Fageria NK. 2009. The use of nutrients in crop plants. CRC Press, Boca Raton, Florida.

FAO (Food and Agriculture Organization). 2000. Fertilizers and their use, 4th Edition. International Fertilizer Industry Association, Rome, Italy.

FAO (Food and Agriculture Organization). 2006. Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fert. Plant Nutr. Bull., 16, Rome, Italy.

Gurpreet S, Jalota SK, Yadvinder S. 2007. Manuring and residue management effects on physical properties of a soil under the rice-wheat system in Punjab, India. Soil and Tillage Research **94 (1)**, 229-238.

Haefele SM, Wopersis MCS, Schloebohm AM, Wiechmann H. 2004. Long term fertility experiment for irrigated rice in the West African Sahel: Effect on soil characteristics. Field Crops Research **85**, 61-77.

Hasan MM, Mian MJA, Hussain MA. 2009. Effects of long term application of manures and fertilizers on soil properties, yield and nutrient uptake by T-Aman Rice. Bangladesh Research Publications Journal **3(1)**, 774-786.

Hoeft RG, Walsh LM, Keeney DR. 1973. Evaluation of various extractants for. available soil sulfur. Soil Science Society of the America Proceeding **37**, 401-404.

Jackson ML. 1973. Soil chemical analysis. Prentice Hall of India Ltd., New Delhi, India.

Janzen HH, Schaalji GB. 1992. Barley response to nitrogen, non nutritional benefits of legume green manure. Plant and Soil **142**, 19-30.

Kaur N, Benipal DS. 2006. Effect of crop residue and farmyard manure on K forms on soils of long term fertility experiment. Indian Journal of Crop Sciences **1(1-2)**, 161-164.

Khan A, Chandra D, Nanda P, Singh S, Ghorai A. 2004. Integrated nutrient management for sustainable rice production. Journal of Agronomy Soil Science **50 (2)**, 161-165.

Ladha JK, Dawe D, Ventura TS, Singh U, Ventura W, Watanabe I. 2000. Long-term effects of urea and green manure on rice yields and nitrogen balance. Soil Science Society of the America Journal **64**, 1993-2001.

Linquist BA, Phengsouvanna V, Sengxue P. 2007. Benefits of organic residues and chemical fertilizer to productivity of rain-fed lowland rice and to soil nutrient balance. Journal of Nutrient Cycling in Agroecosystems **79(1)**, 57-72.

Main MJA. 1990. Air, water and nutrient interaction in paddy soils. A PhD Thesis, Department of Soil Science, BAU, Mymensingh.

Main MJA. 1991. Air, water and nutrient dynamics in paddy soils. Seasonal changes in electro chemical properties of soil. Proceeding of BAU Research Progress **5(1)**, 255-267.

Main MJA, Moslehuddin AZM. 1999. Soil fertility changes under different cropping patterns in long term fertility trials. Proc. Workshop Long Term Expt. Soil Pert. Rice based cropping system, March 8-10, 1999, BRRI, Gazipur.

Mathur GM. 1997, Effect of long-term application of fertilizers and manures on soil properties and yield under cotton-wheat rotation in north-west Rajasthan. Journal of Indian Society of Soil Science **45(2)**, 288-292.

Mgbeze GC, Abu Y. 2010. The effects of NPK and farm yard manure on the growth and development of the African yam bean. African Journal of Biotechnology **9(37)**, 6085-6090.

Mohanty SK, Sharma AR. 2000. Nutrient management in rice. Fert. News **45**, 51-58.

Myint AK, Yamakawa T, Zenmyo T. 2009. Plant growth, seed yield and apparent nutrient recovery of rice by the application of manure and fertilizer as different nitrogen sources on paddy soils. Journal of Faculty of Agriculture, Kyushu University **54**, 329-337.

Myint AK, Yamakawa T, Kajiharaand Y, Zenmyo T. 2010. Application of different organic and mineral fertilizers on the growth, yield and nutrient accumulation of rice in a japanese ordinary paddy field. Science World Journal **5(2)**, 47-54.

Narayan D, Lal B. 2006. Effect of green manuring on soil properties and yield of wheat under different soil depths in Alfisols under semi-arid conditions in central India. Bulletin of the National Institute of Ecology **17**, 31-36.

Oo AN, Banterng A, Polthanee A, Trelo-Ges V. 2010. The effect of different fertilizers management strategies on growth and yield of upland black glutinous rice and soil property. Asian Journal of Plant Sciences **9(7)**, 414-422.

NMA (National Meteorological Agency). 2009. Period averages and climatologically standard normal's. Unpublished, Gambella Branch Office, Ethiopia.

Ohyama N, Katono M, Hasegawa T. 1998. Effects of long term application of organic materials to the paddy field originated form Aso volcanic ash on the soil fertility and rice growth. In: Effects on the rice growth and nutrient uptake for the initial three years. Proceeding, Faculty of Agriculture, Kyushu Tokai University **17**, 9-24.

Okwuagwu MI, Alleh ME, Osemwota IO. 2003. The effects of organic and inorganic manure on soil properties and yield of okra in Nigeria. African Crop Science Proceedings **6**, 390-393.

Olsen SR, Somers LE. 1982. Phosphorus: In: A. L. Page (eds.) Methods of soil analysis, 2nd Edition. AM. Soc. Agron., 9, Part 2, Madison, Wisconsin, USA.

laniappan SP, Annadurai K. 1999. Organic Farming: Theory and Practice. Scientific Publishers, Jodhpur, India.

Palm CA, Murwira HK , Carter SE. 1998. Organic matter management: from science to practice. In: Waddington SR, Murwira HK, Pa Kumwenda JDT, Hikwa D, Tagwira F, eds. Soil Fertility Research for Maize Based Farming System in Malawi and Zambabwe. Proceedings of the Soil Fertility Network Results and Planning Workshop, Mutare, 7-11 Jul 1997, Soil Fert Net/CIMMYT, Harare, 173-177

Pattanayak SK, Mishra KN, Jena MK, Nayak RK. 2001. Evaluation of green manure crops fertilized with various phosphorus sources and their effect on subsequent rice crop. Journal of the Indian Society of Soil Science **49**, 285-291.

Prakash YS, Bhadoria PBS, Rakshit A, Wais A. 2002. Response of basmati rice to integrated nutrient sources in lateritic soil of Eastern India. Italian Journal of Agronomy **6(2)**, 143-150.

Prasad B, Sinha SK. 2000. Long-term effects of fertilizers and organic manures on crop yields, nutrient balance, and soil properties in Rice-Wheat Cropping System in Bihar. In: Abrol IP, Bronson KF, Duxbury JM, Gupta RK, eds. Long-term soil fertility experiments in rice-wheat cropping systems. Rice-Wheat Consortium for the Indo-Gangetic Plains: Rice-Wheat Consortium Paper Series 6. New Delhi, India, 105-119.

Prasad R, Power JF. 1995. Nitrification Inhibitors for Agriculture, Health and the Environment. Advances in Agronomy **54**, 233-281.

Rani P, Francis H, Kandasamy P , Palaniappan SP. 1991. Integrated nutrient management in Tamil Nadu. Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore.

Rao SA, Srivastava S. 2001. Soil testing for targeted crop response. Fifty Years of Natural Research. Mangement Research, 230-244.

Reddy SR. 2006. Agronomy of field crops. Gayatri Offset Press, New Delhi, India.

Regmi AP, Ladha JK, Pathak H, Pasuquin E, Bueno C, Dawe D, Hobbs PR, Joshy D, Maskey SL, Pandey SP. 2002. Yield and soil fertility trends in a 20-year rice-rice-wheat experiment in Nepal. Soil Science Society of the America Journal **66**, 857-867.

Rhoades JD. 1982. In: Methods of soil analysis, Part 2. 2nd edition (Page, A. L., R. H. Miller and D. R. Keeney, Eds.). America Society of Agronomy, **9** Madison, USA

Rowell DL. 1999. Soil science-Methods and applications.Department of Soil Science, University of Reading, Longman, Singapoor.

Sahlemedhin S, Bekele T. 2000. Procedures for for soil and plant analysis. Ethiopian Agricultural Research Organization, National Soil Research Center, Technical Paper **74**.

Sahrawat KL. 2004. Organic matter accumulation in submerged soils. Advances in Agronomy, **81**: 169-201.

Sarwar G, Hussain N, Schmeisky H, Muhammad S, Ibrahim M, Ahmad S. 2008. Efficiency of various organic residues for enhancing rice-wheat production under normal soil conditions. Pakistan Journal of Botechnology **40**, 2107-2113.

Sarwar G, Schmeisky H, Hussain N, Muhammad S, Tahir MA, Saleem U. 2009. Variations in nutrient concentrations of wheat and paddy as affected by different levels of compost and chemical fertilizer in normal Soil. Pakistan Journal of Biotechnology **41(5)**, 2403-2410.

Sarwar MA, Ibrahim M, Tahir M, Ahmad K, Khan ZI, Valeem EE. 2010. Appraisal of pressmud and inorganic fertilizers on soil properties, yield and sugarcane quality. Pakistan Journal of Botechnology **42(2)**, 1361-1367.

SAS (Statistical Analysis System) Institute. 2003. SAS Version 9. 1.2 © 2002-2003. SAS Institute, Inc., Cary, NC.

Shah Z, Ahmad MI. 2006. Effect of integrated use of farm yard manure and urea on yield and nitrogen uptake of wheat. Journal of Agricultural and Biological Science **1(1)**, 60-65.

Sharma SN, Prasad R, Singh S. 1995. The role of mungbean residues and *Sesbania aculeata* green manure in the nitrogen economy of rice-wheat cropping system. Plant and Soil **172**, 123-129.

Sharma SN, Prasad R. 1999. Effect of *Sesbania* green manuring and mungbean residue incorporation on productivity and nitrogen uptake of a rice-wheat cropping. Bioresource Technology **67**, 171-175.

Sharma SN, Prasad R, Gangaiah B, Ram M. 2008. Comparative effect of organic and inorganic nutrition on productivity, sustainability and profitability of basmati rice-wheat cropping system. In: Menon MK, Paul YS, Muralidhara N, eds. Global Organic Agribusiness: India Arrives. India Organic 2008 Seminar, Division of Agronomy, Indian Agricultural Research Institute, New Delhi, India, 57-65.

Singh AK, Amgain LP, Singh SS. 1998. Integrated nutrient management in rice-wheat system under midland situation. pp. 450-451. In: Extended Summaries of 21st International Congress on Agronomy, held at New Delhi, during November 23rd, New Delhi, India.

Singh KN, Prasad B, Sinha SK. 2001. Effect of integrated nutrient management on a Typic Haplaquant on yield and nutrient availability in a rice-wheat cropping system. Australian Journal of Agricultural Research **52**, 855-858.

Singh YV, Singh BV, Pabbi S, Singh PK. 2007. Impact of organic farming on yield and quality of BASMATI rice and soil Properties. Indian Agricultural Research. Institute, New Delhi, India.

Singh Y, Singh B, Ladha JK, Khind CS, Gupta RK, Meelu OP, Pasuquin E. 2004. Long-term effect of organic inputs on yield and soil fertility in the rice-wheat rotation. Soil Science Society of the American Journal **68**, 845-853.

Suzuki A. 1997. Fertilization of rice in Japan. Japan FAO Association, Tokyo, Japan.

Titilola AO. 2006. Effects of fertilizer treatments on soil chemical properties and crop yields in a cassava-based cropping system. Journal of Applied Sciences Research **2(12)**: 1112-1116.

Tomar VPS, Narain P, Dadhwal KS. 1992. Effect of perennial mulches on moisture conservation and soil building properties through agro forestry. Agroforestry Systems **19(3)**, 241-252.

Uenosono S, Nagatomo M. 1998. Effect of application of only manure on yield and quality of paddy rice. Kyushu Agricultural Research **60**, 56.

Vasundhara R. 2006. Studies on soil properties as influenced by organic farming in northern transitional zone of Karnataka. M.Sc. Thesis, Department of Soil Science and Agricultural Chemistry, UAS, Dharwad, India.

Walkely A, Black CA. 1954. An examination of digestion methods for determining soil organic matter and proposed modification of the chromic acid titration methods. Soil Science Journal **37**, 29-38.

Whalen JK, Chang C, Clayton GW, Carefoot JP. 2000. Cattle manure amendments can increase the pH of acid soils. Soil Science Society of the American Journal **64**: 962-966.

Xu ZH, Saffigna PG, Myers RJK, Chapman L. 1993. Nitrogen cycling in leucaena (*Leucaena leucocephala*) alley cropping in semi-arid tropic: I. Response of maize growth to addition of nitrogen fertilizer and plant residues. Plant and Soil **148**, 73-82.

Yadav RL, Yadav DS, Singh RM, Kumar A. 1998. Long-term effects of inorganic fertilizer inputs on crop productivity in a rice-wheat cropping system. Nutrient Cycling in Agroecosystem **51**, 193-200.