Effect of Farmyard Manure and Inorganic Fertilizers on the Growth, Yield and Moisture Stress Tolerance of Rain-fed Lowland Rice

Tilahun-Tadesse F[1*], Nigussie-Dechassa R[2], Wondimu Bayu[3], Setegn Gebeyehu[4]

[1]Amhra Region Agricultural Research Institute, Ethiopia. [2]Haramaya University, Ethiopia
[3]ICARDA, Ethiopia. [4]Ethiopian Institute of Agricultural Research, Ethiopia
[*]Corresponding author: tilahuntade@yahoo.com

Abstract

The effect of integrated farmyard manure (FYM) and inorganic nitrogen (N) and phosphorous (P) fertilizers on growth, yield, and terminal moisture stress tolerance of rain-fed lowland rice was assessed in a field experiment carried out at Fogera plains, in north-western Ethiopia during the main cropping seasons of 2010 and 2011. Treatments were factorial combinations of three rates of FYM (0, 7.5, and 15 t ha^{-1}), three rates of nitrogen (0, 60, 120 kg N ha^{-1}) and three rates of phosphorus (0, 50, and 100 kg P_2O_5 ha^{-1}). The experiment was laid out as a randomized complete block design replicated three times per treatment. Data were collected on rice yield and yield components. Leaf area index (LAI), Crop Growth Rate (CGR), Net Assimilation Rate (NAR) and harvest index (HI) were computed. Economic analysis was also performed by estimating costs of alternative uses of FYM and inorganic fertilizers as well as grain and straw prices. Analysis of the results revealed that applying FYM at 15 t ha^{-1} combined with 120 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1} increased grain yield by 123% and 38% compared to the negative (0-0-0 kg ha^{-1} FYM-N-P_2O_5) and positive (0-120-100 kg ha^{-1} FYM-N-P_2O_5) controls, respectively. Similarly; LAI, CGR, NAR, the number of filled spikelets per panicle, N and P uptake,biomass yield, and grain protein content as well as agrophysiological efficiency of N and P were significantly enhanced in response to increasing the rates of FYM and inorganic N and P fertilizers. It was observed that 15 t ha^{-1} FYM combined with 120 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1} resulted in the maximum grain yield, grain protein content, and terminal moisture stress escape. Though grain yield continued increasing significantly upto the highest combinations, results of the economic analysis showed that the maximum net benefit was obtained in response to the application of 7.5 t ha^{-1} FYM combined with 120 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1}.

Key words: FYM, integrated,lowland, nitrogen, phosphorous, rain-fed, rice.

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1. Introduction

Rice (*Oryza sativa* L.) is the most important cereal crop in the world. The crop is a staple food crop for nearly half of the world's population, most of whom living in developing countries. Rice is mostly grown in the lowlands under fully irrigated or rain-fed conditions. Rain-fed lowland rice occupies approximately 35% of the global rice area. Moisture stress and multiple nutrient deficiencies are among the key factors constraining sustainable rain-fed rice production in many countries (Satyanarayana *et al*., 2002). It is estimated that 50% of the world rice production is affected more or less by drought. As the global climate change continues, water shortage and drought have become an increasingly serious constraints limiting rice production worldwide (Guan *et al*., 2010). Rice is particularly sensitive to drought stress and even mild drought stress can result in significant yield reduction (Guan *et al*., 2010). Flowering and heading are the most sensitive stages to drought as water stress at these stages leads to high spikelet sterility (Tsuda *et al*., 2010). Once sterility occurs, there is no way for the plant to compensate, thus incomplete grain filling and finally greater yield reduction is inevitable (Yoshida 1981; Tsuda *et al*., 2010). To combat the challenges of drought, various adaptation strategies such as establishment of irrigation facilities, rain water harvesting, and use of drought resistant rice varieties have been used (Haefele and Bouman, 2009; Guan *et al*., 2010; Dejene and Lemlem, 2012). Another important mechanism to moderate drought damage is improved nutrient management (Haefele and Bouman, 2009). There are strong indications for the positive interactions between plant nutrient status and yield performance under drought (Haefele and Bouman, 2009). Mineral-nutrient status of plants plays a critical role in increasing plant resistance to drought stress (Haefele and Bouman, 2009; Tsuda *et al*., 2010; Waraich *et al*., 2011). Under low nutrient concentrations in soil, plants have to absorb more water to be able to take up the same amount of mineral nutrients than they would from soil with satisfactory fertility (Waraich *et al*., 2011).

Even in intensive cultivation with excessive use of chemical fertilizers, reduction in soil fertility and yield of rice has become common (Singh and Singh, 2000; Satyanarayana *et al*., 2002). Continuous use of inorganic fertilizers leads to deterioration in soil chemical and physical properties, biological activity and generally in soil health (Mahajan *et al*., 2008). Nutrients supplied exclusively through chemical sources, though enhance yield initially, lead to unsustainable productivity over the years (Satyanarayana *et al*., 2002; Mahajan *et al*., 2008). The negative impacts of chemical fertilizers, coupled with their high prices, have prompted the interest in the use of organic fertilizers as source of nutrients (Satyanarayana *et al*., 2002; Mahajan *et al*., 2008). Organic materials such as FYM have traditionally been used by rice farmers (Satyanarayana *et al*., 2002). FYM application has been reported to improve crop growth by supplying plant nutrients including micronutrients as well as improving soil physical, chemical, and biological properties (Dejene and Lemlem, 2012). FYM provides a better environment for root development by improving the soil structure. Ibrahim *et al*. (2010) reported a significant increase in rice root length and root volume with FYM application which indicates that the better root development would allow the plant to exploit more water under water stress conditions (Dejene and Lemlem, 2012). Faster water infiltration rate due to enhanced soil aggregation is the other benefit of FYM amendments to soil (Bhatacharyya *et al*., 2008). In this way, water becomes available to rice plants for a longer duration. Under conditions of drought, plants supplied with FYM will take longer time to wilt than plants not supplied with the organic fertilizer (Singh and Singh, 2000). Nevertheless, animal manures cannot meet crop nutrient demands over large areas because they contain limited quantities of available nutrients and are labour-intensive for processing and application due to their bulky nature (Jobe, 2003).

Many research findings have shown that neither inorganic fertilizers nor organic sources alone can result in sustainable productivity (Satyanarayana *et al*., 2002; Jobe, 2003). Furthermore, the price of inorganic fertilizers is increasing and becoming unaffordable for resource-poor smallholder farmers. The best remedy for soil fertility management is, therefore, a combination of both inorganic and organic fertilizers, where the inorganic fertilizer provides nutrients and the organic fertilizer mainly increases soil organic matter and improves soil structure and buffering capacity of the soil (Jobe, 2003). The combined application of inorganic and organic fertilizers, usually termed integrated nutrient management, is widely recognized as a way of increasing yield and or improving productivity of the soil sustainably (Mahajan *et al*., 2008). Several researchers (Singh and Singh, 2000; Mahajan *et al*., 2008) have demonstrated the beneficial effect of integrated nutrient management in mitigating the deficiency of many secondary and micronutrients. Identifying the optimum dose of integrated nutrient application is, however, required for maintaining adequate supply of nutrients for increased yield. Different recommendations on the rates of organic-inorganic fertilizer combination have been given for rice production in different parts of the world. Ethiopia is an importer of inorganic fertilizers. On the otherhand, the country has high population of livestock and FYM is readily available. These scenarios necessitate the use of integrated nutrient management in rice production. However, research on integrated nutrient management for rice production has not been yet conducted in Ethiopia. This study was, therefore, conducted to study the effect of the combined application of FYM and inorganic N and P fertilizers on the growth, yield, and moisture stress tolerance of rain-fed lowland rice and to determine optimum rates of combined FYM and inorganic N and P fertilizers for improved productivity of the crop.

2. Materials and methods

2.1. The study site

The study was conducted at Fogera plain in northwestern Ethiopia during the 2010 and 2011 cropping seasons. Fogera plain is located at 13^0 19' latitude, 37^0 03' longitude, and at the altitude of 1815 m above sea level. Eleven-year (2001-2011) meteorological data of the area indicates that in the main cropping season (June-October) the area has mean annual minimum and maximum temperatures of 13.5^0C and 26.1^0C, respectively. Rainfall of the area is uni-modal, mainly falling from June to October, and amounts to 1205 mm. The soil is Vertisol with a clay content of 71.25%. It is slightly acidic (pH 5.90) and the 20 cm soil horizon contains 0.22% total N, 12.64 ppm available P (Olsen), 0.93 cmol (+) kg^{-1}exchangeable K, 3% organic carbon and 52.9 cmol (+) kg^{-1} CEC. According to Bernard (1993), the total N and available P contents of the soil are medium while the organic matter content is low. According to Roy *et al* (2006), the exchangeable potassium content and CEC are high.

2.2. Tretaments and Experimental Design

Treatments consisted of three rates of FYM (0, 7.5, and 15 t ha^{-1}), three rates of N (0, 60, 120 Kg N ha^{-1}) and three rates of P (0, 50, 100 kg P_2O_5 ha^{-1}). The experiment was laid out as a randomized complete block design in a factorial arrangement and replicated three times per tretament. Gross and net plot sizes were 4 m x 5 m and 3 m x 4 m, respectively. Treatments were assigned to each plot randomly. Sun-dried FYM collected from Andasa Livestock Research Center was applied on a dry weight basis a month before planting and thoroughly mixed with the soil. The N, P and K contents of the FYM used in the experiment and the relative N, P, and K additions to the soil were determined (Tables 1 and 2). All the P and half of the N fertilizers for the respective inorganic N and P treatments were applied at planting. The remaining half of the inorganic N fertilizer was applied at tillering stage. Prior to planting, surface (0–20 cm) soil samples, from twelve spots across the experimental field, were collected, composited, and analyzed for determining soil physicochemical properties following the procedure outlined by Page *et al*. (1982). The rice seed was broadcast by hand at the seed rate of 140 kg ha^{-1}. Weeds were removed by handweeding three times (at early tillering, maximum tillering, and booting stages). No insecticide or fungicide was applied since no serious insect or disease incidences occurred. Harvesting was done manually using hand sickles. Urea, Diammonimum phosphate, and TSP were used as inorganic N and P sources, whereas FYM was used as an organic fertilizer. A rice variety called X-Jigna was used as a test crop.

Data on leaf area at heading was measured and calculated following the method of Yoshida (1981):

$$\text{Leaf area (cm}^2) = L \times W \times K$$

Where, L is leaf length, W is maximum width of the leaf and K is a correction factor of 0.75.

Leaf area index (LAI) was also calculated by employing the formula of Yoshida (1981):

$$\text{LAI} = \frac{\text{Sum of the leaf area of all leaves}}{\text{Ground area of field where the leaves have been collected}}$$

Crop Growth Rate (CGR) and Net Assimilation Rate (NAR) for the duration from planting to heading were computed using the equations developed by Hunt (1978) as cited by Ahmad *et al*. (2009):

$$\text{CGR} = \frac{1}{A} X \left(\frac{\Delta DM}{\Delta T}\right) \quad \text{and} \quad \text{NAR} = \frac{1}{LA} X \left(\frac{\Delta DM}{\Delta T}\right)$$

Where, A is area of land, ΔDM is change in Dry matter, ΔT is time variations in day, LA is total leaf area per unit area of land. CGR is expressed as g dry matter m^{-2} land area day^{-1} and NAR is expressed as g dry matter m^{-2} leaf area day^{-1} (Ahmad *et al*., 2009).

Data on the number of days to maturity, number of filled spikelets per panicle, grain and above ground biomass yields were collected from the net plot area at maturity. Grain yield was adjusted to 14% moisture content. N and P concentrations in the aboveground biomass were determined from plant samples collected from each plot at maturity.

N and P uptakes were calculated as:

$$\text{Nutrient uptake } (Kg\ ha^{-1}) = \frac{Nutrient\ concentration\ (\%)\ X\ weight\ of\ dry\ matter\ (kg\ ha^{-1})}{100}$$

Agrophysiological Efficiency (APE) is defined as the economic yield (grain) obtained per unit of nutrient absorbed (Ladha *et al*., 2005). It is calculated as:

$$APE = \frac{\text{Grain yield of fertilized plot (kg)} - \text{Grain yield of unfertilized plot (kg)}}{\text{(NUfp plot (kg) of Straw+Grain)} - \text{(NUu plot (kg) of Straw+Grain)}}\ \text{kg kg}^{-1}$$

Where "NUf plot" is nutrient use of fertilized plot and "NUu plot" is nutrient use of unfertilized plot.

Harvest index (HI) was calculated as the ratio of grain yield to above ground dry biomass yield. Rough rice grain protein content was determined using "Infratec 1241-NIR Analysis for Grain and Flour" instrument (FOSS Company, Denmark).

Data were subjected to analysis of variance using the SAS software (SAS Institute, 2003). Homogeneity of variance was tested using Barlett's test as described by Gomez and Gomez

(1984) and the F-test was not significant. Thus, combined analysis of the two-year data was performed. Differences among treatment means were comapraed using the least significant difference test at 5% level of significance. To identify the economic optimum rate of fertilizer combinations economic analysis was done using the CIMMYT partial budget analysis methodology (CIMMYT, 1988). Average grain price of ETB 7 kg^{-1} and straw price of ETB 60 t^{-1} and Diammonium phosphate (DAP),urea and FYM costs of ETB 12 kg^{-1}, ETB 10 kg^{-1}, and ETB 500 t^{-1}, respectively were used for the analysis. It was estimated that 3 and 4 mandays were needed to apply 7.5 t ha^{-1} and 15 t ha^{-1} FYM, respectively. The labour cost for FYM application was estimated to be Birr 30 per manday's. Following the CIMMYT partial budget analysis methodology, total variable costs (TVC), gross benefits (GB) and net benefits (NB) were calculated. Then treatments were arranged in an increasing TVC order and dominance analysis was performed to exclude dominated treatments from the marginal rate of return (MRR) analysis. A treatment is said to be dominated if it has a higher TVC than the treatment which has lower TVC next to it but having a lower net benefit. A treatment which is non-dominated and having a MRR of greater or equal to 50% and the highest net benefit is said to be economically profitable.

Table 1. Organic matter (OM), N, P, and K composition of the FYM used in the experiment

Year	OM (%)	N (%)	P (%)	K (%)
2010	10.5	1.83	0.49	1.92
2011	11.3	2.02	0.58	2.75

Table 2. OM, N, P, and K additions to the soil form the FYM

Year	7.5 t ha^{-1} FYM				15t ha^{-1} FYM			
	OM (kg ha^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	OM (kg ha^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
2010	787.5	137.3	36.8	144.0	1575.0	274.5	73.5	288.0
2011	847.5	151.5	43.5	206.3	1695.0	303.0	87.0	412.5

3. Results

3.1 Phenological and growth parameters

The number of days required for the rice plants to mature was influenced by the main effect of FYM, nitrogen, and phosphorus as well as by the interactions of N x P and FYM x N x P (Table 3). When the rates of phosphorus and manure were kept at zero, increasing the rate of nitrogen from 0 to 60 kg N ha^{-1} did not change the number of days required to reach maturity. However, at these rates of phosphate and manure; increasing the rate of nitrogen from 60 to 120 kg N ha^{-1} significantly hastened maturity of the rice plants. At the nil level of phosphate, increasing the rate of manure from 0 to 7.5 or 15 t ha^{-1}, hastened maturity of the rice plants in when the rates of N were increased to 60 and 120 kg N ha^{-1}. However, at nil rates of P and N application, maturity of the crop was prolonged across all levels of manure application. Further increases in the phosphate fertilizer across all rates of manure and nitrogen generally led to shortened days to maturity of the rice crop. The smallest numbers of maturity days were recorded for the treatments of 15 t $manure^{-1}$ combined with 60 or 120 kg N ha^{-1} with or without any phosphate application. The most prolonged numbers of days for the maturity of the crop were recorded for the treatments with nil application rates of all three fertilizers as well as the treatment with 60 kg N ha^{-1} with no phosphate and nitrogen application (Table 4). The analysis of variance revealed that leaf area index (LAI) at heading responded significantly to the main effects of FYM, N, P as well as the interaction effects of FYM x N and FYM x N x P (Table 3). The highest LAI at heading was recorded when the highest rates of FYM, N and P were applied in combination. The lowest LAI occurred in response to the application of the lowest rates of nitrogen or FYM or phosphorus (Table 4). However, increasing the rate of nitrogen and manure to the highest levels without applying phosphorus also led to the lowest leaf area index (Table 4).

Significant differences in CGR were observed for the main effects of FYM, N and P and for the interaction effect of FYM x N x P (Table 3). When the rates of phosphate and manure were kept at nil, increasing the rates of nitrogen from 0 to 60 kg N ha^{-1} increased CGR significantly, but no maximum value of the parameter was attained. However, when phosphorus was increased to 50 or 100 kg P_2O5 ha^{-1}, the highest CGR values were obtained already at the combined application of 15 t ha^{-1} manure and 120 kg N ha^{-1} and the combined application of 15 t manure ha^{-1} with 60 kg P_2O5 ha^{-1} and 120 kg N ha^{-1}. This shows that increasing the rate of phosphorus had a more determining effect on CGR than increasing the rate of either manure or nitrogen (Table 5). Similarly, net assimilation rate (NAR) was significantly influenced by the main effects of FYM and N as well as by the interaction effects of FYM x N x P interaction (Table 3). The highest NAR values were recorded when 7.5 t manure ha^{-1} was combined with 60 or 120 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1} or when 15 t ha^{-1}manure was combined with 60 or 120 kg N ha^{-1} and 0, 50, or 100 kg P_2O_5 ha^{-1}. This shows that dry matter was most influenced by manure application (Table 5).

The number of filled spikelets per panicle responded significantly to the single effects of FYM and N, as well as to the interactions of N x P and FYM x N x P (Table 6). When the rates of phosphate and manure were kept at nil, the number of filled spikelet increased significantly in response to increasing the rate of nitrogen from 0 to 60 kg N ha^{-1}. However, at theses rates of phosphate and manure, the number of filled spikelet remained unchanged when the rate of nitrogen was further increased to 120 kg N ha^{-1}. However, at nil level of P application, increasing the level of manure to 7.5 t ha^{-1} significantly increased the number of filled spikelet over all three nitrogen rates. The highest number of filled spikelet with nil application of phosphate was obtained in response to the combined application of the highest rate of manure (15 t ha^{-1}) with 60 or 120 kg N ha^{-1}. However, when the level of phosphate was increased to 50 and 100 kg P_2O_5 ha^{-1}, the highest number of filled spikletes was obtained already at the combined application of only half of the highest rate of manure (7.5 t ha^{-1}) over all three rates of N application; as well as with combined application of 15 t ha^{-1} FYM to the three N levels and 50 and 100 kg ha^{-1} P_2O_5. Even the combined application of the 15 t ha^{-1} FYM with 50% of the inorganic fertilizer (60 kg ha^{-1} N and 50 kg ha^{-1} P_2O_5) resulted in significantly higher number of filled spikelets compared to applying 100% inorganic fertilizer (120 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5) alone (Tables 7).The lowest numbers of filled spikelet were recorded for the combined application of nil rates of manure, nitrogen, and phosphorus as well as 120 kg N ha^{-1}. Nil rate of manure combined with all rates of nitrogen and 50 or 100 kg P_2O_5 ha^{-1} also resulted in the lowest number of filled spikelet (Tables 7).

Table 3. Mean squares of days to maturity, leaf area index (LAI) at heading, crop growth rate (CGR) and net assimilation rate (NAR) due to integrated use of FYM, N and P in rain-fed lowland rice grown at Fogera in 2010 and 2011

Source of variation	Days to maturity	LAI	CGR	NAR
FYM	75.049*	4.633*	1370.807*	30.897*
N	124.568*	8.302*	1463.694*	35.683*
P	89.670*	3.406*	370.749*	1.594NS
FYM x N	14.086NS	1.760*	6.619NS	1.16NS
FYM x P	1.309NS	0.056NS	146.409*	2.559NS
N x P	132.621*	0.282NS	135.906*	1.339NS
FYM x N x P	44.107*	1.501*	226.133*	21.49*
Error Mean Square	6.525	0.486	29.989	2.381

* and NS denote significant and non significant differences at $P \leq 0.05$, respectively.

Table 4. Interaction effects of FYM, N, and P fertilizers on days to maturity and leaf area index (LAI) at heading of rice at Fogera in 2010 and 2011

FYM ($t\ ha^{-1}$)	Nitrogen ($kg\ N\ ha^{-1}$)	Phosphorus ($kg\ P_2O_5\ ha^{-1}$)			Phosphorus ($kg\ P_2O_5\ ha^{-1}$)		
		0	50	100	0	50	100
		Days to maturity			LAI at heading ($m^2\ m^{-2}$)		
0	0	134^{A}	133^{AB}	133^{AB}	3.5^{F}	3.8^{EF}	3.9^{EF}
	60	130^{A-D}	128^{C-F}	128^{C-F}	3.8^{EF}	4.0^{DEF}	4.0^{DEF}
	120	129^{B-E}	128^{C-F}	128^{C-F}	4.0^{DEF}	4.3^{C-F}	4.8^{A-F}
7.5	0	133^{AB}	132^{ABC}	132^{ABC}	4.0^{DEF}	4.1^{C-F}	4.2^{C-F}
	60	127^{D-F}	127^{DEF}	126^{D-G}	4.2^{C-F}	4.4^{B-F}	4.6^{A-F}
	120	127^{D-F}	125^{EFG}	124^{FG}	5.4^{A-D}	5.6^{ABC}	5.9^{AB}
15	0	133^{AB}	129^{B-E}	130^{A-D}	3.9^{EF}	4.3^{C-F}	4.5^{B-F}
	60	126^{D-G}	125^{EFG}	124^{FG}	4.9^{A-F}	5.1^{A-E}	5.2^{A-E}
	120	125^{EFG}	124^{FG}	122^{G}	4.4^{C-F}	5.3^{A-E}	6.2^{A}
CV (%)		18.1			16.4		

Means followed by the same letters within each growth parameter are not different at $P \leq 0.05$.

Table 5. Interaction effects of FYM, N and P fertilizers on Crop Growth Rate (CGR) and Net Assimilation Rate (NAR) of rice at Fogera in 2010 and 2011

FYM (t ha^{-1})	Nitrogen (kg N ha^{-1})	Phosphorus (kg P_2O_5 ha^{-1})			Phosphorus (kg P_2O_5 ha^{-1})		
		0	50	100	0	50	100
		CGR (g dry matter m^{-2} land area day^{-1})			NAR (g dry matter m^{-2} leaf area day^{-1})		
0	0	7.6^{K}	8.9^{JK}	11.6^{IJK}	3.5^{G}	4.9^{FG}	5.4^{D-G}
	60	10.7^{IJK}	18.1^{E-I}	19.0^{E-I}	5.2^{E-G}	6.8^{B-F}	6.9^{B-F}
	120	13.4^{H-K}	15.2^{G-K}	22.3^{D-H}	5.6^{C-G}	5.7^{C-G}	6.7^{B-F}
7.5	0	11.0^{IJK}	11.6^{IJK}	18.3^{E-I}	5.3^{D-G}	5.0^{FG}	6.9^{B-F}
	60	26.0^{B-F}	26.7^{B-E}	26.9^{B-E}	6.6^{B-F}	7.0^{B-F}	7.8^{A-D}
	120	22.7^{C-G}	30.1^{BCD}	30.9^{BCD}	6.7^{B-F}	7.6^{B-E}	8.1^{ABC}
15	0	15.1^{G-K}	17.5^{F-J}	18.5^{E-I}	6.1^{B-F}	6.1^{B-F}	6.4^{B-F}
	60	30.5^{BCD}	31.3^{BC}	33.8^{AB}	8.3^{AB}	8.4^{AB}	8.3^{AB}
	120	24.2^{C-F}	34.5^{AB}	42.6^{A}	8.5^{AB}	8.6^{AB}	10.2^{A}
CV (%)			18.0			22.78	

Means followed by the same letter for each growth parameter are not significantly different at 5% level of significance.

Table 6. Mean squares of number of filled spikelet per panicle due to integrated use of FYM, N and P in rain-fed lowland rice grown at Fogera in 2010 and 2011

Source of variation	Number of filled spikeletes per panicle
FYM	33855.424*
N	3705.003*
P	1185.831NS
FYM x N	55.130NS
FYM x P	69.792NS
N x P	3278.794*
FYM x N x P	7283.744*
Error Mean Square	533.176

* and NS denote significant and non significant differences at P≤0.05, respectively.

Table 7. The interaction effect of FYM, N and P fertilizers application on the number of filled spikelets per panicle of rice at Fogera in 2010 and 2011

FYM (t ha^{-1})	Nitrogen (kg N ha^{-1})	Phosphorus (kg P_2O_5 ha^{-1})		
		0	50	100
		Number of filled spikelet per		
0	0	88^{J}	94^{J}	91^{J}
	60	132^{E-I}	118^{HIJ}	114^{HIJ}
	120	105^{IJ}	122^{G-J}	123^{F-J}
7.5	0	136^{D-I}	133^{E-I}	150^{C-H}
	60	148^{D-H}	157^{B-G}	157^{B-G}
	120	148^{D-H}	162^{A-E}	162^{A-E}
15	0	106^{IJ}	163^{A-E}	169^{A-E}
	60	171^{A-D}	187^{ABC}	186^{ABC}
	120	171^{A-D}	191^{AB}	197^{A}
	CV (%)	22.8		

Means followed by the same letters within each growth parameter are not different at P≤0.05.

3.2 Aboveground biomass yield, grain yield, and grain protein content

Aboveground biomass yield significantly responded to the main effects of FYM, N and P and to the interaction effects of N x P and FYM x N x P (Table 8). Keeping the rate of phosphate application at nil and increasing the rates of manure and nitrogen did not result in consistent increases in aboveground biomass yield of the rice crop. However, when the rate of phosphorus was increased to 50 kg P_2O_5 ha^{-1}, increasing the rates of both manure and nitrogen consistently increased aboveground biomass yield. When the rate of phosphate was increased further to 100 kg P_2O_5 ha^{-1}, the aboveground biomass yield increased further significantly with the increase in the rates of both fertilizers. Thus, the highest aboveground biomass yields were obtained in response to the combined application of the highest rate of phosphate (100 kg P_2O_5 ha^{-1}) and the highest rate of manure (15 t ha^{-1}) with 60 or 120 kg N ha^{-1}.

Keeping the rates of phosphate and manure application at nil over all three rates of nitrogen application did not increase grain yield. Similarly, increasing the rate of manure to 7.5 t ha^{-1} and keeping both N and P rates at nil did not result in any increase in grain yield. However, at the nil rate of phosphate, increasing the rates of manure to 7.5 and the rates nitrogen to 60 or 120 kg N ha significantly increased grain yield of the rice crop. Increasing the rate of manure to 15 t ha^{-1} at nil rate of phosphate further increased grain yield of the crop over all three rates of nitrogen application. Increasing the rate of nitrogen from 0 to 60 and up to 120 kg N ha^{-1} and that of phosphate to 50 kg P_2O_5 ha^{-1} did not increase grain yield when the rate of manure remained nil. However, when the rate of manure was increased from 0 to 7.5 t ha^{-1} at 50 kg P_2O_5 ha^{-1}, the grain yield increased significantly over all three rates of nitrogen. Increasing the rate of phosphate to 100 kg P_2O_5 ha^{-1} and that of nitrate from zero to 60 kg N ha^{-1} did not increase grain yield when the rate of manure remained nil. However, at this level of phosphate supply, when the rate of manure was increased to 7.5 t ha^{-1}, increasing the rate of nitrogen significantly increased grain yield. Increasing the rate of manure further to 15 t ha^{-1} at 100 kg P_2O_5 ha^{-1} further increased grain yield over all rates of nitrogen. Hence, the highest grain yield was attained at the combined application of the highest rates of all three fertilizers i.e., 15 t manure ha^{-1} with 100 kg P_2O_5 ha^{-1} and 120 kg N ha^{-1} (Table 9).

Harvest index did not respond to any of the treatments and their interactions (Table 8). However, increasing trends in harvest indices with the increased application rates of the combined fertilizers were observed where harvest indices of 0.24 for the negative control and 0.41 for the highest fertilizer combination (15 t ha^{-1}FYM, 120 kg N $ha^{-1}$and 100 kg P_2O_5 ha^{-1}) were recorded.

The main effects of FYM and nitrogen significantly influenced protein concentration in the rice grain, However, this parameter was not affected by the main effect of phosphorus. FYM and phosphorus interacted to influence protein concentration in rice grains. The interaction effect of the three fertilizers (FYM x N x P) also influenced this parameter (Table 8). The highest protein concentration in the grains was obtained in response to the combined application of the highest rates of the three fertilizers whereas the lowest was recorded for the combined application of nil rates of manure and nitrogen over all three rates of phosphorus (Table 10).

Table 8. Mean squares of aboveground biomass yield, grain yield, harvest index and grain protein content due to integrated use of FYM, N and P in rain-fed lowland rice grown at Fogera in 2010 and 2011

Source of variation	Above ground biomass yield	Grain yield	Harvest index	Grain protein
FYM	12.835*	3.589*	0.033NS	0.284*
N	48.021*	6.254*	0.038NS	0.745*
P	29.428*	11.700*	0.012NS	0.021NS
FYM x N	2.818NS	0.119NS	0.025NS	0.069*
FYM x P	3.203NS	2.157*	0.041NS	0.043NS
N x P	15.112*	3.822*	0.055NS	0.066*
FYM x N x P	8.115*	5.112*	0.042NS	0.102*
Error Mean Square	3.918	0.193	0.023	0.025

* and NS denote significant difference and non significant difference at P≤0.05, respectively.

Table 9. The interaction effect of integrated FYM, N and P application on aboveground biomass and grain yields of rice at Fogera in 2010 and 2011

FYM (t ha^{-1})	Nitrogen (kg N ha^{-1})	Phosphorus (kg P_2O_5 ha^{-1})			Phosphorus (kg P_2O_5 ha^{-1})		
		0	50	100	0	50	100
		Aboveground biomass yield (t ha^{-1})			Grain yield (t ha^{-1})		
0	0	9.7^{HI}	9.5^{I}	11.2^{E-I}	2.27^{J}	2.29^{J}	2.32^{J}
	60	10.5^{GHI}	10.5^{GHI}	12.5^{C-G}	2.35^{J}	2.44^{IJ}	2.51^{IJ}
	120	12.0^{C-G}	13.5^{BCD}	12.7^{C-G}	2.48^{IJ}	2.57^{IJ}	3.67^{DE}
7.5	0	10.8^{F-I}	10.5^{GHI}	9.5^{I}	2.34^{J}	3.10^{FGH}	3.42^{EFG}
	60	11.5^{D-I}	11.7^{C-I}	11.9^{C-H}	2.92^{GHI}	3.48^{EF}	4.26^{CD}
	120	11.8^{C-H}	13.3^{B-E}	13.8^{B-E}	3.16^{FG}	3.76^{DE}	4.42^{C}
15	0	10.8^{F-I}	11.0^{F-I}	10.5^{GHI}	2.92^{GHI}	3.44^{EF}	3.43^{EF}
	60	12.5^{C-G}	12.8^{B-F}	15.0^{AB}	3.23^{FG}	4.21^{CD}	4.93^{B}
	120	11.0^{F-I}	13.0^{B-F}	15.8^{A}	3.49^{EF}	3.87^{DE}	5.01^{A}
	CV (%)		19.70			12.68	

Means followed by the same letters within each growth parameter are not different at P≤0.05.

Table 10. The interaction effect of FYM, N and P fertilizers on the grain protein content (%) of rice grains at Fogera in 2010 and 2011

FYM ($t\ ha^{-1}$)	Nitrogen ($kg\ N\ ha^{-1}$)	Phosphorus ($kg\ P_2O_5\ ha^{-1}$)		
		0	50	100
0	0	7.00^{I}	7.23^{F-I}	7.17^{HI}
	60	7.27^{FGH}	7.33^{D-H}	7.30^{E-H}
	120	7.34^{D-H}	7.40^{D-H}	7.57^{BCD}
7.5	0	7.17^{HI}	7.17^{HI}	7.43^{C-G}
	60	7.33^{D-H}	7.47^{C-F}	7.53^{B-E}
	120	7.33^{D-H}	7.53^{B-E}	7.77^{B}
15	0	7.20^{GHI}	7.40^{D-H}	7.47^{C-F}
	60	7.20^{GHI}	7.43^{C-G}	7.53^{B-E}
	120	7.40^{D-H}	7.67^{BC}	8.17^{A}
CV (%)			17.14	

Means followed by the same letters are not different at $P \leq 0.05$.

3.3 Nitrogen and Phosphorus uptake and use efficiency

Aboveground biomass N uptake was significantly affected by the main effects of FYM and N as well as the interaction effects of FYM x N, N x P, and FYM x N x P (Table 11). The aboveground biomass P uptake was significantly affected by the main effects of FYM and P and the interaction effects of FYM x P, N x P and FYM x N x P (Table 11). The highest N uptake was recorded for the combined application of the highest rates of the three fertilizers. The lowest N uptake was scored for the combined application of nil rate of manure and nil and 60 rates of nitrogen over all rates of phosphorus. The highest value of N uptake was closely followed by the N uptake value recorded for the combined application of 15 t manure with 60 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1} (Table 12) The N uptake obtained in response to the highest rates of the three fertilizers exceeded the uptake of the nutrient recorded in response to nil application rates of the three fertilizers 2.34-fold. When the rates of P and manure application were kept at nil, increasing the rate of nitrogen from zero to 50 or 120 did not change the magnitude of P uptake. Similarly, at zero level of phosphate and nitrogen, increasing the level of manure to 7.5 t ha^{-1} did not increase P uptake. However, at zero level of phosphate increasing the rate of manure from zero to 7.5 to 15 t ha^{-1} significantly enhanced P uptake over all three rates of nitrogen. Further increases in phosphate and manure rates increased P uptake over all three nitrogen rates. Thus, the highest P uptake values were recorded for the combined application of 15 t manure ha^{-1}, 60 or 120 kg N ha^{-1} with 100 kg P_2O_5 ha^{-1}. These values were closely followed by the values of P uptake recorded for the combined application of 15 t manure ha^{-1}, 60 or 120 kg N ha^{-1} with 50 kg P_2O_5 ha^{-1} (Table 12). The P uptake obtained in response to the highest combined application of manure and phosphate with 60 kg N ha^{-1} significantly exceeded the P uptake recorded in response to nil application rates of the three fertilizers 3-fold.

Nitrogen APE showed significant response to the main and interaction effects except for P and its interaction with FYM (Table 11). Similarly, phosphorous APE responded significantly to all main and interaction effects of treatments except for N and its interaction with FYM (Table 11). Agro physiological efficiency for N was highest for the integrated application of of 15 t FYM ha^{-1}, 60 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}, 15 t FYM ha^{-1}, 60 kg N ha^{-1} and 100 kg ha^{-1} P_2O_5, 15 t FYM ha^{-1}, 120 kg N ha^{-1}, and 100 kg ha^{-1} P_2O_5. In addition, nill application of all three fertilizers also led to the highest APE of nitrogen. The lowest APE values of nitrogen were recorded for 0 rate of P ha-1 combined with 60 and 120 kg N ha-1 with all rates of manure (Table 13).

When the rates phosphate was kept at 50 kg P_2O_5 ha^{-1} and that of manure remained nil, increasing the rate of nitrogen from 0 to 60 kg N ha^{-1} did not change the APE of P. However, at this level of phosphate, increasing the rate of nitrogen to 120 kg N ha^{-1} significantly increased APE of P. The APE of P remained unchanged up to the highest level of manure combined with all rates of nitrogen except at the rate of 60 kg N ha^{-1} and 120 kg N ha^{-1}. The highest APE of P was recorded at the combined application of 50 kg P_2O_5 ha^{-1} and 15 t manure ha^{-1} with 60 kg N ha^{-1}. However, at the combined application of 50 kg P_2O_5 ha^{-1}, 15 t manure ha^{-1}, and 120 kg N ha^{-1}, APE of P reduced significantly. Increasing the rate of phosphate to 100 kg P_2O_5 ha^{-1} did not improve APE of P markedly. The lowest APE of P was recorded for the treatments with nil rates of nitrogen and manure combined with 100 kg P_2O_5 ha^{-1} (Table 14). Thus, the highest APE of the pre-coded treatment of 50 kg P_2O_5 ha^{-1} and 15 t manure ha^{-1} with 60 kg N ha^{-1} exceeded the lowest APE of the nutrient recorded at nil rates of nitrogen and manure combined with 100 kg P_2O_5 ha^{-1} by about 336% (Table 14).

Table 11. Mean squares of rice biomass N and P uptakes, and nitrogen and phosphorous agro-physiological efficiencies (APE) of due to integrated use of FYM, N and P in rain-fed lowland rice grown at Fogera in 2010 and 2011

Source of variation	Plant N uptake	Plant P uptake	Nitrogen APE	Phosphorous APE
FYM	50416.235*	4168.338*	115.219*	1200.837*
N	33788.569*	74.951NS	112.696*	128.220NS
P	321.109NS	1761.358*	38.128NS	817.804*
FYM x N	1974.733*	56.17NS	105.034*	212.321NS
FYM x P	239.041NS	694.708*	48.684NS	710.804*
N x P	1430.731*	313.157*	62.476*	581.018*
FYM x N x P	1520.849*	254.213*	69.817*	531.776*
Error Mean Square	472.837	89.714	19.207	119.663

* and NS denote significant and non significant differences at P≤0.05, respectively.

Table 12. Interaction effects of FYM, N and P application on rice biomass N and P uptake of rice at Fogera in 2010 and 2011

FYM (t ha^{-1})	Nitrogen (kg N ha^{-1})	Phosphorus (kg P_2O_5 ha^{-1})			Phosphorus (kg P_2O_5 ha^{-1})		
		0	50	100	0	50	100
		N uptake (kg N ha^{-1})			P uptake (kg P ha^{-1})		
0	0	81.6^{K}	79.4^{K}	91.8^{JK}	26.5^{P}	28.4^{OP}	35.4^{K-O}
	60	93.4^{JK}	95.6^{JK}	112.2^{IJK}	28.0^{P}	30.6^{NOP}	43.4^{F-I}
	120	122.2^{HIJ}	145.5^{GHI}	125.1^{HIJ}	33.8^{L-P}	40.8^{I-L}	43.2^{G-J}
7.5	0	122.6^{HIJ}	114.7^{H-K}	110.1^{IJK}	33.1^{M-P}	42.6^{H-K}	39.7^{I-M}
	60	149.1^{FGH}	161.9^{EFG}	161.5^{EFG}	36.0^{J-N}	46.9^{E-I}	50.3^{D-G}
	120	162.0^{EFG}	197.1^{CDE}	199.2^{CD}	43.4^{F-I}	52.2^{DE}	60.0^{BC}
15	0	138.7^{GHI}	135.0^{GHI}	136.1^{GHI}	45.4^{E-I}	48.5^{D-H}	54.6^{CD}
	60	181.7^{DEF}	193.3^{CDE}	246.6^{AB}	50.6^{DEF}	62.5^{B}	81.7^{A}
	120	194.0^{CDE}	225.1^{BC}	272.6^{A}	44.4^{F-I}	62.6^{B}	80.6^{A}
CV (%)			14.51			19.68	

Means followed by the same letters within each growth parameter are not different at P≤0.05.

Table 13. Interaction effect of FYM, N and P fertilizers on the agrophysiological efficiency (APE) of nitrogen in rice at Fogera in 2010 and 2011

FYM (t ha^{-1})	Nitrogen (kg N ha^{-1})	Phosphorus (kg P_2O_5 ha^{-1})		
		0	50	100
0	60	22.11^{ABC}	17.37^{CDE}	16.13^{C-F}
	120	8.13^{G}	15.04^{C-G}	17.16^{CDE}
7.5	60	9.63^{FG}	15.06^{C-G}	14.92^{C-G}
	120	11.08^{EFG}	12.90^{D-G}	18.48^{BCD}
15	60	9.60^{FG}	24.86^{AB}	28.43^{A}
	120	10.85^{EFG}	11.15^{EFG}	27.49^{A}
CV (%)		27.18		

Means followed by the same letters are not different at P≤0.05.

Table 14. Interaction effect of FYM, N and P fertilizers on the agrophysiological efficiency (APE) of phosphorous in rice at Fogera in 2010 and 2011

FYM (t ha^{-1})	Nitrogen (kg N ha^{-1})	Phosphorus (kg P_2O_5 ha^{-1})	
		50	100
0	0	40.82^{E}	18.99^{F}
	60	41.34^{DE}	51.30^{B-E}
	120	46.81^{B-E}	53.29^{B-E}
7.5	0	51.46^{B-E}	57.06^{B-E}
	60	59.23^{BCD}	53.61^{B-E}
	120	57.91^{B-E}	61.03^{BC}
15	0	53.18^{B-E}	41.31^{DE}
	60	82.90^{A}	48.19^{BCD}
	120	44.27^{CDE}	64.69^{B}
CV (%)		21.24	

Means followed by the same letters are not different at P≤0.05.

Table 15. Results of the economic analysis for integrated use of FYM, N and P in rain-fed lowland rice grown at Fogera in 2010 and 2011

FYM (tha^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	MRR (%)
0	0	0	0	16336	-
0	120	100	4368	21864	126.6
7.5	60	100	6528	23751	87.3
15	60	100	9993	25121	39.6

3.4 Economic analysis

Results of the economic analysis showed that the maximum net benefit (ETB 23751 ha^{-1}) with an acceptable MRR was obtained from the combined application of 7.5 t FYM ha^{-1}, 120 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1} (Table 15). This combination has resulted in a net benefit advantage of Birr 7415 ha^{-1} over the control treatment (0-0 N-P_2O_5 kg ha^{-1}).

4. Discussion

4.1. Phenological and growth parameters

Due to poor soil fertility management, delayed maturity is common in farmers' fields, which often exposes the crop to terminal moisture stress. . The fertilizers had synergistic effect on the number of days required for the maturity of the crop. The longest durations for maturity of the rice crop were recorded for the treatments with nil application of all three fertilizers as well as the treatment with the application of 60 kg N ha^{-1} with no phosphate and nitrogen application On the other hand, the shortest durations of maturity were recorded for the treatments of 15 t^{-1} FYM combined with 120 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5. The stated treatment shortened the maturity duration by 12 and 6 days compared to no fertilizer application (0-0 N-P_2O_5 kg ha^{-1}) and application of 120-100 N-P_2O_5 kg ha^{-1} inorganic fertilizer, respectively. Thus, maturity was hastened markedly when inorganic fertilizer was applied in combination with FYM. This result implies that rice crop fertilized with the combined application of FYM and inorganic N and P matured earlier, signifying that it would escape terminal moisture stress which is a common occurrence in the area. Therefore, the use of FYM and inorganic fertilizers in the production of lowland rice could be used as a strategy to enable the crop to escape terminal moisture stress. In line with this finding, Wonprasaida *et al*. (2006) also reported a reduction in days to maturity in rice in response to combined FYM and inorganic fertilizer application.

LAI determines the efficiency of photosynthesis and photosynthetic surface area and thus, is an important determinant of plant productivity (Yoshida, 1981). However, in farmers' fields, owing to poor soil fertility management, it is common to see small and narrow leaves of the rice crop.

This has obviously contributed to the poor productivity and yield of the crop under farmers' management condition. Nevertheless, in the present investigation LAI had increased by about 77% with the combined application of 15 t ha^{-1} FYM, 120 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5 over the no fertilized crop. This increase in LAI could be attributed to enhanced production of carbohydrate, which might have resulted in increased leaf expansion. In agreement to this result, Naing *et al*. (2010) reported that combined application of 10 t ha^{-1} FYM with 50-22 N-P kg ha^{-1} resulted in a 41.3 % increase in LAI of rice at heading compared to no fertilizer application. Aziz *et al*. (2010) also reported a two-fold increase in leaf area index in rice with the application of 15 t ha^{-1}FYM. In the present study, the maximum rice LAI of 6.06 at heading was observed with the application of 15 t ha^{-1} FYM together with 120 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5. According to Yoshida (1981), a rice crop can attain maximum LAI values of 10 or greater at heading time. A LAI of 5–6 is the critical optimum to achieve maximum photosynthesis during the reproductive stage of rice (Yoshida, 1981). Therefore, in this study, the rice plants attained critical leaf area indices for higher productivity at the highest rates of FYM and nitrogen with or without P application. This results also signified the more prominent roles played by nitrogen and FYM than phosphorus in enhancing leaf area index of the crop. In fact, phosphorus enhances leaf expansion and leaf area index (Marschner, 2012). However, the relatively low role of phosphorus in enhancing leaf area index of the rice plants in this study may be attributed to the relatively higher availability of the nutrient than nitrogen in the soil (medium level) as exhibited by the soil test results. Increased CGR and NAR were recorded with the combined application of FYM and N and P fertilizers. Increasing the rate of phosphorus had a more determining effect on CGR than increasing the rate of either manure or nitrogen The increased leaf area observed with the application of FYM and N and P fertilizers could have resulted in higher radiation use efficiency which in turn might have led to higher photoassimilate production and thus to increased CGR and NAR (Naing *et al*., 2010). Similarly, Ahmad *et al*. (2009) reported increases in LAI, leaf photosynthesis, CGR and NAR of rice with proper soil nutrient management.

Rice is very sensitive to poor soil fertility and moisture stress and in cases the crop would be exposed to poor soil fertility and moisture stress, the proportion of unfilled spikelet will extremely increase (Satyanarayana *et al*., 2002; Naing *et al*., 2010). This would have negative consequences on the productivity of the crop. It is common to see such scenarios in farmers' rice fields in Fogera due to farmers' poor soil fertility management practices. However, in the present experiment, the number of filled spikelets per panicle increased by as much as 82-124% with the combined application of FYM and N and P fertilizers over the no fertilized crop. This implies that through simple improved soil fertility management practices, the productivity of rice could be increased because of reduced number of unfilled spikeletes. This result is supported by that of Naing *et al*. (2010) who stated that the potential number of grains per panicle was influenced by the plants' nutritional status. Naing *et al*. (2010) further reported that combined application of 10 t ha^{-1} FYM with 50-22 kg N-P ha^{-1} resulted in a 30.7% increase in rice filled grains number per panicle as compared to no fertilizer application.

4.2. Aboveground biomass yield, grain yield, and grain protein concentration

Rice straw is an important resource for livestock feed and construction of houses in the Fogera plain (Tilahun *et al*., 2012). Improvement in the rice biomass yield has great implication for the Fogera farmers where mixed crop-livestock farming is predominant as it means an increased availability of livestock feed. The observed increase in biomass yield with integrated application of FYM and inorganic N and P fertilizers is believed to help the farmers by ensuring more supply of rice straw as a feed resource particularly during the dry season. On top of being feed of high value for livestock e and for its utility in plastering of walls of houses in construction, the straw will generate more household income through sale (Tilahun *et al*., 2012). However, due to no rate fertilizer application and frequent terminal moisture stress, farmers in Fogera plain are getting lower rice straw and grain yields. In the current experiment, it was observed that the combined application of 15 t ha^{-1} FYM together with 120 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5 produced additional 2.79 and 1.39 t ha^{-1} rice grain compared to the negative (0-0-0 kg ha^{-1} FYM-N-P_2O_5) and positive (0-120-100 kg ha^{-1} FYM-N-P_2O_5) controls, respectively. This has yield advantages of 123% and 38% compared to the respective controls. The result further revealed that optimum straw and grain yields of the crop were attained at the highest combined application rates of the three fertilizers. These results are consistent with that of Mahajan *et al*. (2008) and Naing *et al*. (2010) who reported increased straw and grain yields in rice with the combined application of FYM and inorganic fertilizers. In the present research, applying 50% of the N and P fertilizer rates (60 $kgha^{-1}$ N and 50 kg ha^{-1} P_2O_5) in combination with 15 t ha^{-1} FYM resulted in a 15% increase in grain yield over the crop which received 100% of the N and P fertilizer rates (120 kgha^{-1} N and 100 kg ha^{-1} P_2O_5) alone. This implies that by combining inorganic fertilizers with FYM farmers could reduce the need for inorganic fertilizers while still increasing their productivity. Similarly, Bodruzzaman *et al*. (2010) also reported that plots with 10 t ha^{-1} FYM plus 75% NPKSZn produced equivalent or higher rice yields as 100% NPKSZn.

The significant increase in grain yield in response to the combined application of organic and inorganic fertilizers could be attributed to increased nutrient and soil moisture availability and thus increased uptake of nutrients by plant roots. This might be attributed to the nutrient supplying capacity of the FYM as well as its propensity to improve the soil physio-cochemical properties. Neither FYM nor chemical fertilizers alone could be sufficient to increase yield sustainability under cropping system where nutrient turnover in soil plant system has been much higher (Satyanarayana *et al*., 2002). However, in an integrated nutrient managment, FYM can maintain plant nutrients in the available forms for longer periods due to improved soil organic matter (SOM) and soil physico-chemical and biological characteristics (Singh and Singh, 2000; Aziz *et al*., 2010). Chemical fertilizers, on the other hand, offer nutrients which are readily soluble in soil solution and thereby make nutrients instantly available to plants (Aziz *et al*., 2010). FYM is also reported to be a good source of nutrients such as phosphorus, potassium, and silica (Yoshida 1981; Mahajan *et al*., 2008) and also it enhances availability of secondary and micronutrients (Aziz *et al*., 2010; Bodruzzaman *et al*., 2010).

It is known that sufficient nutrient supply would improve the grain protein concentration in rice grains (Salem, 2006). In the current study, rice grain protein concentrations increased by 1.17 and 0.6% with the combined application of 15 t ha^{-1} FYM, 120 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5 over the negative (0-0-0 kg ha^{-1} FYM-N-P_2O_5) and positive (0-120-100 kg ha^{-1} FYM-N-P_2O_5) controls, respectively. Most commercial rice varieties have grain protein concentrations below 10%. However, there are variations in rice grain protein concentration because of management factors like fertilizer applications (Chandel *et al*., 2011). Similar to the present observation, Chandel *et al*. (2011) reported high grain protein concentration in rice grains in response to the combined application of FYM and inorganic fertilizers.

4.3. Nitrogen and Phosphorus nutrients uptake and use efficiency

The chemical composition of any plant is an important parameter to compare the performance of treatments applied. In this study, both N and P uptake values were higher with the combined applications of FYM and N and P fertilizers. Nitrogen and phosphorus uptakes values have increased by as much as 202-234% and 204-208%, respectively with the combined application of FYM and N and P fertilizers over the no fertilized crop. The increase in N uptake could be ascribed to slow and continued supply of the nutrients, coupled with reduced N losses via denitrification or leaching, which may have improved the synchrony between plant N demand and supply from the soil. This proposition is consistent with that of Haile *et al.* (2012) who reported that N uptake by wheat crop was significantly enhanced when application of the highest dose of N fertilizer was done synchronized with the time high demand of the plant for uptake of the nutrient. The higher P uptake could be attributed to the increased P availability and increased root growth of the crop. According to Aziz *et al*. (2010) root growth in plants receiving FYM is higher and hence would increase nutrient uptakes. Yassen *et al*. (2010) further suggested that, FYM application increased the transfer of elements between the solid phase and soil solution which again could be a reason for the higher nutrient uptakes. It was also indicated that the activity of soil microorganisms under higher FYM applications which gain might have led to increased nutrient uptake (Yassen *et al*., 2010). The present finding is in agreement with the findings of Hossain *et al*. (2010) who reported higher N and P uptakes in rice with FYM application over no fertilizer and inorganic fertilizers application.

Application of 15 t ha^{-1} FYM, 60 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5 is among some of the treatments that gave highest nitrogen agro-physiological efficiency. On the other hand the highest phosphorus agro physiological efficiency was recorded for the integrated application of 15 t ha^{-1} FYM, 60 kg ha^{-1} N and 0 kg ha^{-1} P_2O_5. In line with the present finding, Naing *et al*. (2010) reported that significantly higher agro-physiological N and P use efficiencies of rice were observed with organic-inorganic mixed fertilizers compared to chemical fertilizers alone. Higher uptake efficiency contributes directly to the better use of applied nutrients and reduced losses from the system (Naing *et al*., 2010).

4.4 Economical analysis

Farmers in Fogera plain are producing rice year after year with application of neither inorganic fertilizers nor FYM. This scenario has led to soil nutrient depletion and deterioration in the physical quality of the soil. The farmers may have the opportunity to enhance their crop yields and improve their livelihoods through adopting proper soil fertility management practices. For instance, in the current study, with the combined application of 7.5 t ha^{-1} FYM, 120 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5, a 45% increase in net benefit was attained over the control treatment, which implies a very high increase in farmers' income with a simple improvement in crop management. However, though, the economic maximum was found at the application of 7.5 t ha^{-1} FYM with 120 kg N ha-1 and 100 kg P2O5 ha^{-1}, it would be sensible to recommend application of 15 t ha^{-1} FYM in view of sustaining the physico-chemical properties of the soil. In line with this Naing *et al*. (2010) reported that even though the estimated net income for combined FYM-inorganic fertilizer application is not attractive as compared to inorganic fertilizers alone, farmers should consider that the long term use of inorganic fertilizers to pre-empt deterioration in soil physical and chemical properties. Therefore, they should apply higher rates of FYM together with inorganic fertilizers so as to improve both rice production and soil fertility.

Conclusion

Generally, it is understood that the positive impacts of FYM application on crop yield and soil properties can be realized after long term applications. However, the current results from a single year FYM addition highlighted the potential of FYM in improving the productivity of rice. In addition to improving the long term productivity of the soil, this soil fertility management approach has resulted to a large cost saving of mineral fertilizers. The combined use of FYM and inorganic fertilizers enhanced rice productivity and yield through increasing LAI, filled spikeletes number, by increasing nutrient uptake and utilization. Using FYM in combination with inorganic fertilizers has also shortened days to maturity, which is a good strategy to enable the plant to escape terminal moisture stress in rain-fed lowland rice production. Thus, considering the poor soil fertility management by resource poor smallholder farmers and the high cost of mineral fertilizers, combined use of FYM and mineral fertilizers at justifiable rates is central to enhance the productive capacity of the soil and to improve rice productivity. From sustainable rice production and immediate economic point of view, combined application of 7.5 t ha^{-1} FYM, 120 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5 is recommended for rice production in the study area.

References

Ahmad A, Iqbal S, Ahmad S, Khaliq T, Nasim W, Husnain Z, Hussain A, Zia-Ul-Haq M and Hoogenboom G (2009) Seasonal growth, radiation interception, its conversion efficiency and biomass production of *Oryza sativa* L. Under diverse agroenvironments in Pakistan. *Pakistan Journal of Botany, 41(3): 1241-1257*.

Aziz T, Ullah S, Sattar A, Nasim M, Farooq M and Mujtabakhan M (2010). Nutrient Availability and Maize (*Zea mays*) Growth in Soil Amended with Organic Manures. *International Journal of Agriculture and Biology 12(4):621–624*.

Bernard PK (1993) Evaluation and interpretation of soil analytical data. National Soil service project, FAO/UNDP/ETH/87/010. Ministry of Agriculture, Addis Ababa, Ethiopia. 78Pp.

Bhatacharyya R, Kundu S, Prakash V, and Gupta HS (2008) Sustainability under combined application of mineral and organic fertilizers in a rainfed soybean-wheat system of the Indian Himalayas. *European Journal of Agronomy* 28: 33-46.

Bodruzzaman M, Meisner CA, Sadat MA and Hossain MI (2010) Long-term effects of applied organic manures and inorganic fertilizers on yield and soil fertility in a wheat-rice cropping pattern. 19th World Congress of Soil Science, Soil Solutions for a Changing World 1 – 6 August 2010, Brisbane, Australia. P 23-44.

Chandel G, Banerjee S, See S, Meena R, Sharma DJ and Verulkar SB (2011) Effects of Different Nitrogen Fertilizer Levels and Native Soil Properties on Rice Grain Fe, Zn and Protein Contents. *Rice Science 17(3): 213-227*.

CIMMYT (1988) From Agronomic Data to Farmer Recommendations. An Economic Training Manual. Completely Revised Edition. CIMMYT, Mexico, D. F., Mexico. 79 pp.

Dejene M and Lemlem M (2012) Integrated Agronomic Crop Managements to Improve Tef Productivity Under Terminal Drought. Water stress. Ismail Md. Mofizur Rahman and Hiroshi Hasegawa (eds.). Published by InTech Open Science. Pp 235-254.

Gomez KA and Gomez AA (1984) Statistical Procedures for Agricultural Research. 2nd Edn., John Wiley and Sons Inc., New York, pp 328-332.

Guan YS, Serraj R, Liu SH, Xu JL, Ali J, Wang WS, Venus E, Zhu LH and Li ZK (2010) Simultaneously improving yield under drought stress and non-stress conditions: a case study of rice (Oryza sativa L.). *Journal of Experimental Botany 61(15):4145–4156*.

Haefele SM and BAM Bouman (2009) Drought-prone rain-fed lowland rice in Asia: Limitations and management options. In: Serraj J, Bennett J, Hardy B, editors. Drought frontiers in rice: crop improvement for increased rain-fed production. Singapore: World Scientific Publishing and Los Baños (Philippines): International Rice Research Institute. Pp 211-232.

Haile D, Dechassa N and Ayana A (2012) Nitrogen use efficiency of bread wheat: Effects of nitrogen rate and time of application. Journal of Soil Science and Plant Nutrition, ahead of print Epub 25-Sep-2012.

Hossain AT, Rahman F, Saha PK and Solaiman ARM (2010) Effects Of Different Aged Poultry Litter on the Yield and Nutrient Balance In Boro Rice Cultivation. *Bangladesh Journal of Agricultural Research* 35(3) : 497-505.

Hunt R (19780 Plant Growth Analysis. The Inst. of Bio. Studies in Bio. Edward Arnold (Pub.) Ltd. pp 8-38.

Ibrahim M, Hassan A, Arshad M and Tanveer A (2010) Variation in root growth and nutrient element concentration in wheat and rice: Effect of rate and type of organic materials. *Soil and Environment 29(1): 47 – 52*.

Jobe (2003) Integrated Nutrient Management for Increased Rice Production in the Inland Valleys of The Gambia. In: Sanyang S., A. Ajayi and A.A. Sy (eds). Proceedings of the Second Biennial Regional Rice Research Review. WARDA Proceedings Series no. 2 Vol 1. Pp 35-41.

Ladha JK, Pathak H, Krupnik TJ, Six J and Kessel C (2005) Efficiency of fertilizer nitrogen in cereal production: retrospects and prospects. *Advances in Agronomy, 87:85-156*.

Mahajan A, Bhagat RM and Gupta RD (2008) Integrated nutrient management in sustainable rice-wheat cropping system for food security in India. *SAARC Jnournal of Agriculture 6(2):29-32*.

Marschner P (2012) Marschner's Mineral Nutrition of Higher Plants, 3rd ed. London, UK: Academic.

Naing A, Banterng P, Polthanee A and 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*.

Page AL, Miller RH and Keeney DR (1982) *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties*. 2nd edn. Soil Science Society of America; Madison, Wisconsin, U.S.A.

Roy RN, Finck A, Blair GJ and Tandon HLS (2006) Plant nutrition for food security. A guide for integrated nutrient management. Food and Agricultural Organization of United Nations. FAO *Fertilizer and Plant Nutrition Bulletin* 16. Rome.348p.

Salem AKM (2006) Effect of Nitrogen Levels, Plant Spacing and Time of Farmyard Manure Application on the Productivity of Rice. *Journal of Applied Sciences Research 2(11): 980-987*.

Satyanarayana V, Prasad PV, Murthy VRK and Boote KJ (2002) Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. *Journal of Plant Nutrition 25(10):2081–2090*.

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

Sewagegne T (2011) An Overview of Rice Research in Ethiopia. In: Kebebew Assefa Dawit Alemu, Kiyoshi Shiratori and Abebe Kirub (eds). Challenges and Opportunities of Rice in Ethiopian Agricultural Development. FRG II Project, Empowering Farmers' Innovation Series No. 2. ©EIAR/JICA, Addis Ababa, Ethiopia. Pp 33-38.

Singh VP and Singh RK (2000) Rainfed Rice: A Sourcebook of Best Practices and Strategies in Eastern India. International Rice Research Institute. 292 p.

Tilahun G, Berhe K, Hoekstra D and Bogale A (2012) Rice value chain development in Fogera *woreda* based on the IPMS experience. Nairobi, Kenya: ILRI. 23pp.

Tsuda M, Endo and Hirai Y (2010) Effects of Top Dressing on Growth and Panicle Dry Weight as Affected by Soil Water Stress at the Early Panicle-Development Stage in Rice (*Oryza sativa* L.). *Plant Production Science 13(1): 37-44*.

Waraich AE, Ahmad R, Saifullah MY and Ehsanullah A (2011) Role of mineral nutrition in alleviation of drought stress in plants. *Australian Journal of Crop Science 5(6):764-777*.

Wonprasaida S, Khunthasuvona S, Sittisuangb P and Fukai S (2006) Performance of contrasting rice cultivars selected for rainfed lowland conditions in relation to soil fertility and water availability. *Field Crops Research 47(2–3):267–275*.

Yassen A, Khaled A, Sahar SM and Zaghloul M (2010) Response of wheat to different rates and ratios of organic residues on yield and chemical composition under two types of soil. *Journal of American Science 6(12):858-864*.

Yoshida S (1981) Fundamentals of rice crop science The International Rice Research Institute, Los Baños, Laguna, Philippines. 269 Pp.