Agronomic Performance of Integrated Use of Organic and Inorganic Fertilizers on Rice (Oryza sativa L.) in Tselemti District of North-Western Tigray, Ethiopia

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Abstract
A variety of biological and economic interactions between crop and livestock make crops-livestock integration appealing to the Ethiopian farmers. The decline in soil fertility is widespread in Tigray, Ethiopia, and is threatening food security. The ever-increasing price of inorganic fertilizers (IF) is becoming a main problem for majority of farmers. Hence there is a need for alternative low cost soil fertility enhancing technologies. Farmyard manure (FYM) can be an alternative but its shortage limits its use as organic fertilizer. In addition to its nutrient supply, farmyard manure improves the physicochemical conditions of soils due to its residual effect in the soil's fertility status. Integrated Nutrient Management (INM) which implies combined application of organic and inorganic fertilizers and helps to overcome the problems associated with single application of either source for enhanced crop productivity. Based on this fact, a 2 factorial asymmetric experiment was conducted, in 2011/12, to evaluate the effect of integrated application of inorganic fertilizers and FYM on yield and yield components of upland rice. A 4x3 factorial experiment consisting of four levels of inorganic fertilizers (0, 25, 50 and 75 kg/ha) and three levels of FYM (0, 6 and 9 t/ha) was laid out in RCB Design with three replications. Rice (variety: NERICA-3) was used as an indicator crop and planted in rows. The results revealed that application of 9t/ha FYM with 75 kg/ha of IF resulted in grain yield of 44.4Ql/ha ($p < 0.05$) and delayed flowering and maturity by about 14.67 days and 20.33 days respectively. However, more such studies need to be conducted at various soil and agro-climatic conditions to generate more detailed information.
Keywords: DAP, Fertilizers, FYM, INM, NERICA, Rice, Urea, Tigray, Yield.

1. INTRODUCTION

Rice (*Oryza sativa L.*) has supported a greater number of people for a longer period of time than any other crop since it was domesticated between 8,000 to 10,000 years ago (Fairhurst and Dobermann, 2002). Because of its political, economic, and social significance, rice remains the most important crop grown in the world (Greenland, 1997). The high input agriculture during the period of the Green Revolution had many critics across a wide spectrum of dissatisfaction which includes the long-term effects of pesticides, herbicides, antibiotics and fertilizers on the environment and human health (Evans, 1998). As Rahman (2003) quoted, delayed consequences of the Green Revolution technology on the environment and the question of sustainability of agricultural growth received priority only recently. This concern has promoted a number of initiatives to promote the adoption and diffusion of more sustainable agricultural technologies. The impact of increased fertilizer use on crop production has been large, but ever increasing cost of energy is an important constraint for increased use of inorganic fertilizer particularly for resource poor farmers (Lay, 2002; Assefa, 2005). Furthermore, ecological and environmental concerns over the increased and indiscriminate use of inorganic fertilizers have made research on use of organic materials as a source of nutrients very necessary (Muhammad *et al.,* 2003). Use of chemical fertilizers is an essential component of modern farming but sustainable production of crops cannot be maintained by using only chemical fertilizers; and similarly FYM has long been recognized the most desirable organic fertilizer to improve soil quality but it is not possible to obtain higher crop yield by using organic manure alone due mainly to their unavailability in excess amount (Sarker *et al.,* 2011). Therefore, an integrated nutrient management in which both organic manures and inorganic fertilizers are used simultaneously has been suggested as the most effective method to maintain a healthy and sustainable soil system while increasing crop productivity (Bodruzzaman *et al.,* 2010). The problem of decreasing land fertility, use of high doses of inorganic fertilizers and the ever increasing cost of inorganic fertilizers are factors considered harmful for sustainability of production systems (Adhikari, 2011). Long-term studies done by Bhandari *et al.* (2002) attributed the reduced productivity of the rice system to declining SOM, decreased soil fertility, and occurrence of nutrient imbalances. Hence, integration of legumes, green mannuring and farm yard manures in rice-based cropping systems can increase soil fertility and yield higher than the conventional practices of using inorganic fertilizers alone year after year (Adhikari, 2011). A combination of mineral fertilizers and farmyard manure has been suggested as the most effective method to maintain a healthy and sustainable soil system while increasing crop productivity (Uphoff, 2005; Satyanarayana, 2002; Zelalem *et al.*, 2010; Balesh, 2006).

2. LITERATURE REVIEW

Despite of its relatively recent history of cultivation, rice is among the basic targeted cereal commodities that has received due emphasis in the promotion of agricultural production and expected to contribute to ensuring food security in Tigray, Ethiopia. In addition to its adaptability to Ethiopian climatic conditions, what makes rice to be highly acceptable by farmers is its amenability to be made in to various food items that are culturally used by the Ethiopians (Redda, 2010, Zenna et al., 2008). The fact that it can be made into '*injera'* (*fermented and flattened Ethiopian bread*)', bread, porridge and local drinks is good enough for its rapid adoption. Of course, this is in addition to rice being consumed boiled and mixed with different sauces as is done elsewhere in the world. The other important reason for its great adoption by farmers is the palatability of its straw for livestock (*ibid*). By now rice is one of the strategic cereal crops of Ethiopia in alleviating poverty and insuring food security and got the nick name "*CROP OF THE MILLENNIUM*" (Kebebew, 2011).

However, there are growing evidences that intensive rice production usually using only external fertilizers and with little or no use of organic manure will be a big question for researchers in the near future because of severe fertility deterioration of soils resulting in stagnating or even declining of crop productivity (Ali *et al.* 2009, Quang *et al.,* 2006). Artificial fertilizer usage needs to be rationally used because unwise application of fertilizers negatively affects the soil fertility, future crop productivity and farmers' economy (Lichtfouse, 2011). Furthermore, farmers are arguing that the price of the inorganic fertilizers is getting up and the increased dose is having burning effect on crops. FYM is is an important organic resource for agricultural production in crop-livestock based farming systems like Ethiopia (Hailu, 2010). Thus, there is a lot of potential for use of farmyard manure in the fertilizer schedule of rice and to reduce total dependence on inorganic fertilizers. However, no such study has been done so far for adoption of Integrated Nutrient Management (INM) technologies in Tigray region especially for rice. The present research was therefore, conducted to study the effect of separate and combined application of farmyard manure and inorganic fertilizer on growth, yield and yield components upland rice. The amount of inorganic fertilizer used in most smallholder farming systems falls far below standard extension recommendations, due to poor purchasing power, risk aversion, poor and unreliable rainfall, and lack of significant yield returns. **Mineral/ inorganic fertilizers** require intensive knowhow, high purchasing power, need to be applied seasonally and are highly risky in low rainfall areas. However, FYM, in addition to its nutrient supply, it improves the physicochemical conditions of soils due to its residual effect in the soil's fertility status (Elias, 2002, Place *et al.,* 2003). The FYM production capacity of farmers varies from farmer to farmer and effects of using FYM vary based on the amounts applied. However, availability of FYM in enough amounts is always a concern because it is dependent on the animal holding and family labor (Bodruzzaman *et al.,* 2010; Mahajan *et al.,* 2008; Lay, 2002). An application of farmyard manures at 10 t /ha contributes 30-70 kg N/ha in rice besides leaving a significant residual effect on succeeding crops (Rekhi *et al.,* 2000). Long-term studies on rice have shown increased yield and yield components due to application of farmyard manure and these effects are largely attributed to improved soil organic matter, soil physical, chemical and microbial properties with application of farmyard manure (Bhandari *et al.*, 2002). A study by Hailu (2010) reported that the cumulative biomass yield of fields with FYM was significantly higher than control and mineral fertilizer yields.

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

Tigray, located in the northern tip of Ethiopia is bordered with Afar region in the East, Sudan in the West, Eritrea in the North and Amhara region in the South. It extends from $12^0 13'$ to $14^0 54'$ North latitude and from $36^0 27'$ to $40\ ^0 18'$ East longitudes. It covers an area of 102,000 km^2 and has more than 4 million inhabitants, of whom 85% are rural dwellers (CSA, 2006). The field experiment was conducted at the research station of Maitsebri Agricultural Research Center located in Tselemti Woreda. The research station lies at $13^0$05' North Latitude and $38^0$08' East Longitude and has an altitude of 1350 masl. Tselemti district has an altitude range of 800 to 2870 masl and the altitude of the experimental site is 1350masl. The agro-Ecological Zone of the district is Hot to warm-moist lowlands (M1-7) and Tepid to cool-moist mid highlands (M2-5). The mean annual temperature ranges from a minimum of 15.66 ^oC (November-January) to an average annual maximum of 36.64^oC (February-May). It is a low altitude area with average (5 years) annual rainfall of 1296.5 mm and had a mono-modal pattern. Total rainfall during the growing period of the crop (during the study year) was 912.3mm. Generally, rainfall starts in June and ends in September.

3.1.4 Pre-Sowing Surface Soil and FYM Properties

3.1.4.1 Selected Physical and Chemical Properties of Soil of the Study Site

Physical and chemical analyses of the soil were carried out for the surface composite soil (0-30cm) of the experimental field. The result of the soil analysis (Table 3) showed that the textural class of the surface soil was clay in texture with particle size distribution of 25% sand, 33% silt and 42% clay and chemical characteristics:

pH of 6.08, available phosphorus of 1.2 (ppm), CEC of 57.8 (meq/100gsoil), organic matter of 1.83%, and total nitrogen of 0.1022%. According to Foth and Ellis (1991), the soil is moderately acidic (5.6-6.1) in reaction with a pH of 6.08. Furthermore, according to Landon (1991), the soil at the experimental site had low total N (0.1-0.2%), and low plant available phosphorus (<5ppm) and according to Defoer (2000), deficient soil organic carbon (0.9-1.7). These results explicitly justify the need for the external application of organic or/and inorganic sources based on the base recommendation for the different crops grown in the area. The low organic carbon content (1.06%) in surface soils of the study area obtained might be due to low biomass incorporation to the soil because of its use as a fuel and animal feed. The low amount of organic matter in the soil is also related to environmental conditions, particularly to vegetation, climate and to the history of cultivation. The farmers have been practicing continuous cropping system. In addition to this, total removal of the crop residue might have contributed to the low level of organic matter and total nitrogen.

Table 1: Some Selected physicochemical characteristics of the surface soil (0-30cm) of the experimental site before starting the experiment, at Maitsebri, Ethiopia, 2011.

Characteristics	Unit	Value
Sand	(%)	25
Silt	(%)	33
Clay	(%)	42
Textural Class Name	-	Clay
pH (soil: water=1:2.5)	-	6.08
Organic Carbon	(%)	1.06
Organic Matter	(%)	1.83
EC	(dSm^{-1})	0.32
CEC	(meq/100g soil)	57.8
Total N	(%)	0.1022
Available P	(ppm)	1.2
Available K	(ppm)	130.363

3.1.4.2 Selected Chemical Properties of the Farmyard Manure (FYM)

The chemical composition of the FYM used in the experiment was characterized through laboratory analysis (Table 2). The FYM contained 25.43% organic matter ('Very High', Barber 1994); 1.32% nitrogen ('very high', Landon, 1991); 451.6 ppm available phosphorous ('Very high', Landon, 1991) and 18679.87 ppm of available potassium.

Table 2: Chemical Composition of the Organic Manure (FYM)

Organic material	pH	EC (dSm^{-1})	CEC (meq/100g)	OC (%)	OM (%)	TN (%)	C: N	Av. P (ppm)	Av. K (ppm)
FYM	8.81	10.91	48.40	14.75	25.43	1.3202	11.2	451.6	18699.87

Key: *OC= Organic Carbon; TN=Total Nitrogen; CEC=Cation Exchange Capacity;EC= electrical conductivity.*

3.2 Experimental Material, Treatments, Design and Procedures

Rice cultivar 'NERICA-3' was used as planting material. It is moderately tillering type and could bearing 3-5 effective tillers. Under rain fed conditions, it had a yield potential of 36-42 quintal per hectare under research experiments and 25-40 quintal per hectare under farmers' management. It is moderately tolerant to disease and lodging with an average plant height of 104 cm (Redda, 2010). The treatments consisted of a factorial combination of four levels of inorganic fertilizers and three levels of FYM. The experimental design used was RCBD in 3 x 4 factorial arrangements with three replications. A plot size of 1.4m x 3 m (4.2 m^2) was used. The blocks were separated by 1.5m, whereas plots within a block were 1m apart from each other. Each plot consists of 7 rows of 3m length, with a spacing of 20 cm between rows. The treatments were organic (FYM) and inorganic (DAP plus Urea) sources of plant nutrients with rice as a test crop. The sources of the inorganic fertilizers were DAP (18%N, 46%P_2O_5) and Urea (46%N). Full dose of DAP and half of Urea were applied at the time of planting and the remaining Urea was side dressed at panicle initiation stage of the crop. The source of the manure was cattle manure. There were three levels of the organic fertilizer (FYM) i.e. FYM_1=9t/ha; FYM_2=6t/ha and no manure (Mo=control). The inorganic fertilizer (IF) treatments were comprised of four levels: control (IF_O=no DAP and no Urea), IF_1=75kg/ha DAP + 75kg/ha Urea; IF_2=50kg/ha DAP + 50kg/ha Urea and IF_3=25kg/ha DAP + 25kg/ha Urea. The seeds were sown at a depth of 2.5 cm and seed rate of 70kg/ha was used. All other cultural practices (ploughing, cultivation, seed rate, sowing method, weeding and others) were applied uniformly to all plots as per standard recommendations for the crop. At physiological maturity, grain yield was obtained from the net central five rows with a net area of 2.6m x 1m excluding plants from either end of the rows by 0.2m. Before harvesting, yield parameters such as number of tillers/plant, number of effective tillers/plant, plant height, panicle length etc. were recorded from five randomly selected plants. Grain yield data were recorded after drying, threshing and cleaning of the grain. Straw yield was obtained by subtracting the grain yield from total above ground biomass yield.

3.3 Data Collection

3.3.1. Agronomic Parameters

3.3.1.1 Phonological Observation

Major phonological events such as days to 50% emergence, days to 50% flowering, days to 90% maturity were recorded. These three phonological observations were recorded as number of days starting from sowing date. Days to 50% emergence was recorded when half of the seedlings per net plot area were emerged. Days to 50% flowering was also taken when half of the plant population on the net plot area started to flower. Days to 90% maturity was recorded when 90% of the rice plants turned their leaves yellow or brown. Each phonological stage was determined from visual observation.

3.3.1.2 Crop Growth Observations

Crop growth parameters included plant height and panicle length. Plant height was recorded as the height of plant crown from the ground level. From five randomly sampled plants from each plot, average plant height, numbers of tillers per plant number of spikes per plant, panicle length, number of seeds per panicle, were recorded as per the following details: Number of spikes per head was recorded by counting the branched spikes bearing seeds in the sampled plants. Numbers of seeds per panicle were recorded by counting the total number of seeds of a panicle from five randomly sampled 5 rice plants from each plot. Plant height of the main stem was measured from the ground surface to the tip of the apex using a ruler and expressed in cm.

3.3.1.3 Yield and Yield Components

At maturity all the plants from the net plot area ($2.8m^2$) were harvested and data on grain and straw yield were measured. Grain yield and above ground dry biomass yield per plot were recorded and expressed in Ql/ha. 1000-seed weight was expressed in grams. Harvest index was worked out as the ratio of rice grain yield to total above ground biomass yield multiplied by 100 and was expressed in percentage. Number of tillers per plant and number of effective tillers of the same plants were counted from the five randomly selected and tagged plants. After the leaves turned yellow and the stems brown, plants of the central five rows of the plot were harvested. Threshing was done by collecting the plants from each plot and allowed to dry thoroughly in open sacks so as to prevent grain loss. Then, the yield of each plot was weighed using sensitive balance in kgs and converted to ha basis. Thousand seed weight was determined from the count of 1000 seeds after sun drying and expressed in grams.

3.4. Methods of Data Analysis

3.4.1 Agronomic Data Analysis

All data obtained on crop and soil parameters were subjected to analysis of variance (ANOVA) following a procedure appropriate to a factorial experiment in randomized complete block design as suggested by Gomez and Gomez (1984) and was computed using Gen-Stat 12^{th} statistical software (Gen-Stat, 2009). Treatments that showed significant difference were subjected to DMRT (Duncan Multiple Range Test) for mean separation at 5% level of probability. Simple correlation analysis was also done to determine the association of various agronomic (yield and yield components).

4. RESULTS AND DISCUSSION

4.1. Effects of Organic and Inorganic Fertilizers on Phonological growth, Yield and Yield Components of Rice

4.1.1 Phonological and Growth Observations

As is depicted in Table 3, days to 50% flowering (DF), days to 90% physiological maturity (DM), plant height (PH) and panicle length (PL) were significantly ($P \leq 0.05$) influenced by the main effect of FYM and inorganic fertilizers except that panicle length was not significantly affected by the main effect of FYM.

Table 3: Mean square for DE, DF, DM, PH and PL

Source of variation	*df*	*DE*	*DF*	*DM*	*PH*	*PL*
Rep.	2	**0.36**	**7.44**	**17.69**	**83.08**	**2.99**
M	2	**3.53****	**184.52****	**692***	**84.23***	**4.8**^{ns}
IF	3	**0.92***	**19.51***	**172.3***	**228.7****	**6.52***
M x IF	6	**0.64***	**28.12****	**23.44****	**9.2**^{ns}	**1.57**^{ns}
Residual	24	**0.21**	**4.11**	**80.28**	**22.6**	**1.48**
Total	35					

Key: *df=degree of freedom; M= manure (FYM); IF= inorganic fertilizer; DE= days to emergence; DF= days to flowering; DM= Days to maturity; PH=Plant height; PL= panicle length; ns=non-significant.*

4.1.1.1 Days to 50% Flowering (DF)

With regard to days to 50% flowering, plots that got manure took longer days (max. 84 days) than the inorganic fertilizers (max. 82days) and the two main factors took longer days than the control (71.33days). The effect of the main factors on days to 90% physiological maturity is similar as that of the days to 50% flowering. In both parameters (DF and DM), FYM application took longer days to flower and mature over the application of the inorganic fertilizers (Table 3). A significant ($P \leq 0.05$) difference occurred on the average mean number of days to 50% flowering, 50% flowering and 90% maturity due to FYM and IF (inorganic fertilizers) interaction. The average days to emergence, flowering and maturity took 5-7days, 75-86 days and 100-126 days after planting respectively. The mean shortest days to seed emergence (5 days after planting) were observed when either 9t/ha of FYM is applied along with 75kg/ha of the IF or 75kg of IF is used with zero FYM. The longest days to flowering (114.3 days) were observed where 7.5 t/ha of FYM is incorporated with 50 kg/ha of IF. When FYM is incorporated with IF, the mean shortest days to maturity (103.7 days) were observed when 75kg/ha of IF is applied with no FYM or when 25kg/ha of IF is used with 5t/ha of FYM (Table 4).

4.1.1.2 Days to Maturity (DM)

The results of main effect of different treatments and their interaction in relation to days to flowering and maturity are given in Table 5. Organic and inorganic fertilization significantly influenced days required for flowering and to attain physiological maturity in rice (Table 5). Application of 9t/ha FYM with 75 kg/ha of inorganic fertilizers delayed days to flowering and maturity by about 14.67 days and 11.3 days respectively as compared to the unfertilized treatment (control). Similarly, increasing FYM application from 0 to 9t/ha prolonged the days to flowering by about 13 days than the control. The main effects of organic fertilizers (FYM) and inorganic fertilizers (IF) on the number of days to 90% maturity are depicted in Table 6. A statistically significant ($p<0.05$) difference was observed on the days to 90% maturity due to the two nutrient sources. Use of IF (as DAP and Urea) decreased the number of days to maturity as compared to the organic sources. Greater number of days (122.5) to physiological maturity was recorded when higher dose (9t/ha) of FYM was used as a main factor. The interaction of different rates of recommended dose of inorganic fertilizers with various levels of organic manures (i.e. FYM) had a significant effect on days to maturity (Table 4). The application of 75kg/ha dose of N/P alone significantly reduced the days to maturity as compared to the organic sources which resulted in longest maturity period about 122.5 days (Table 5). This agrees with the findings of Orkaido (2004) who reported that application of commercial fertilizers resulted in increased yields and earlier maturity of maize.

The increase in days to maturity of rice using FYM could be due to the fact that more nitrogen fertilizers increase the vegetative growth of the crop and hence the crop tends to have more number of days to mature than the non-fertilized plots. This research result agrees with the findings of Krishnippa (1989) where he concluded that high level of Nitrogen fertilizers increased the leaf area which increases the amount of solar radiation intercepted and consequently, increases days to flowering, days to physiological maturity, plant height and dry matter production of different plant parts. This result of the experiment disagrees with the findings of Daniel (2006) who reported that integration of organic manure with inorganic fertilizers fasten maturity period of the potato crop at Bako Agricultural Research Center.

4.1.1.3 Plant Height (PH)

Main effect of inorganic and organic fertilizers on the progressive development of plant height of rice is presented in Table 4. There was a significant difference due to the two soil fertility enhancement options (FYM and IF) with respect to plant height. However, use of inorganic fertilizers (DAP and Urea) showed significantly higher plant height as compared to that of use of the organic sources (FYM) in the time course of observations (Table 4). The difference in plant height between the two options was observed at the maturity stages of the crop. Plant height increase in response to the fertilization treatment may be attributed to stem elongation. This could be due most likely to the ready-made nutrient availability of the inorganic fertilizers and the slow nature of nutrient release by the organic sources. The analysis of variance of plant height showed significant differences ($p<0.05$) for the main effects of organic fertilizers and highly significant differences ($p<0.01$) for the main effects of inorganic fertilizers (Table 4). Plant height increased from 70.7 to

76.06 cm as the rate of FYM increased from 0 to 9t/ha. Similarly, the plant height also increased from 67.89 to 79.8cm as the rate of inorganic fertilizer increased from 0 to 75 percent of the recommended rate. The increase in plant height might be due to better availability of N and the enhancing effect of N on the vegetative growth by increasing cell division and elongation (Daniel, 2006). Although the interaction effect of inorganic fertilizers and organic fertilizers on the final plant height was not statistically significant (Table 4). Highest plant height of 83.1cm was recorded when 9t/ha of FYM is used in conjunction with 75kg/ha of inorganic fertilizers which is 18.43cm longer than the control (64.67). Application of 9t/ha of FYM integrated with 75kg/ha inorganic fertilizer had recorded maximum plant height (83.1cm) followed by the combination of 75kg/ha of IF and 5t/ha of FYM which resulted in (79.57 cm). The results of the experiment confirm the findings of Gonzalez et al. (2001) who reported that organic manure and inorganic fertilizer supplied all the essential nutrients at seedling stage resulting in increase of measured variables like the plant height. Generally it was observed that treatments that received both organic and inorganic fertilizer produced plants with more height as compared to plants in unfertilized plots.

4.1.1.4 Panicle Length (PL)

The main effect of inorganic fertilizers had significant effect on the panicle length of rice but the main effects of organic fertilizers and the combined effect of organic and inorganic fertilizers did not significantly influenced the panicle length of rice (Table 4). However, higher mean panicle length (18.4cm) was obtained where 9t/ha of FYM and 75kg/ha of IF were combined while lower mean panicle length (14.23cm) was recorded at the plot of absolute control (treatment 1). Likewise, higher mean panicle length of 17.44cm was observed at the main effect of the inorganic fertilizer with 75kg/ha but which is not significantly different from the level of 50kg/ha inorganic fertilizer (16.91cm). The fact that higher panicle length was observed with higher manure level indicates that N/P nutrients affect the panicle length which directly affects the yield.

Table 4: Rice Phonological and growth parameters as influenced by the integrated nutrient management at Maitsebri, Ethiopia, 2011/12.

Trts	Combinations		DE	DF	DM	PH	PL
	FYM (t/ha)	IF (kg/ha)					
Trt1	0	0	6abc	71.33f	102.7cd	64.67	14.23
Trt2	0	75	5d	77.33de	103.7bc	76.73	16.73
Trt3	0	50	5.667bcd	82.67abc	113a	73.70	16.87
Trt4	0	25	5.333cd	75e	95.33d	68.00	15.20
Trt5	9	0	6abc	83.33abc	111.7a	70.07	16.77
Trt6	9	75	5d	86a	113.7a	83.10	18.40
Trt7	9	50	6.333ab	83.33abc	114.3a	74.87	16.47
Trt8	9	25	6.667a	84.67ab	114a	76.20	16.27
Trt9	6	0	6.667a	81.67bc	112.3a	68.93	16.47
Trt10	6	75	6.667a	82bc	110.7ab	79.57	17.20
Trt11	6	50	6.333ab	80cd	108.7abc	74.00	17.40
Trt12	6	25	6.667a	82.33bc	112.3a	69.77	15.60
CV(%)			7.6	2.51	4.28	6.49	7.37
$LSD_{(0.05)}$			0.776	3.433	7.926	8.05	2.057
SEM(±)			0.21	4.111	21.907	22.599	1.475

Key:*Means within the same column followed by the same letter or no letter do not differ significantly at the5% level of significance; IF= Inorganic fertilizer; FYM= farmyard manure; DE=days to 50% emergence; DF= days to 50% flowering; DM=days to 90% maturity; PL=Panicle length; PH=plant height.*

4.1.2. Yield and Yield Components

The mean square values of the yield and yield components of rice are depicted in Table 5. As a main factor, the inorganic fertilizers had significant effect on all the yield and yield components except for the harvest index; and the organic fertilizer (FYM), had no significant effect only for NSpPP (number of spikes per panicle) and HI (harvest index). On the other hand, the combined effect of organic (FYM) and inorganic sources (DAP and Urea) had significant effect on grain yield (GY), number of tillers per plant (NT) and 1000 seed weight (TSW) but not on the rest yield components of rice (Table 5). The results of the analysis of variance of the main factors and their interaction effects for yield and yield components are given in Tables 6 and 7 respectively. The ANOVA showed that significant differences existed among treatments for most of the parameters for the main effects of both FYM and inorganic fertilizers. The organic source (FYM) showed significant effects except for NT, NSpPP and harvest index (HI). The inorganic sources, as a main factor, showed significant effects for all the yield and yield components except for the HI (Table 5).

Table 5: ***Mean square for NT, NSpPP, NSePP, AGBY, GY, SY, HI and TSW***

Source of variation	df	NT	NSpPP	NSePP	AGBY	GY	STYld	HI	TSW
Replication	2	0.07	0.57	126.39	3.78	0.98	8.59	8.69	0.01
M	2	**0.38ns**	**1.57^{ns}**	**145.02***	**536.79****	**143.9****	**126.67****	**6.73^{ns}**	**2.89****
IF	3	**3.29****	**4.65***	**201.86***	**758.1****	**151.33****	**240.84****	**7.64^{ns}**	**1.16****
M x IF	6	**0.57***	**0.53^{ns}**	**80.44^{ns}**	**44.34^{ns}**	**18.26***	**13.99^{ns}**	**11.86^{ns}**	**0.654***
Residual	24	0.21	1.09	43.09	28.28	6.3	14.12	5.27	0.24
Total	35								

Key: *IF=inorganic fertilizers; M=farmyard manure; NT=Number of tillers per plant; NSpPP=Number of spikes per panicle; NSePP= Number of seeds per panicle; AGBY=above ground biomass yield; GY=Grain yield; SY=Straw yield; HI=Harvest index; TSW=thousand seed weight; df=degrees of freedom, * significant at p<0.05, ** significant at P<0.01; ns= non- significant*

Table 6: Yield and Yield components of rice as influenced by the main effects of IF and FYM at Maitsebri, Ethiopia, 2012.

Variable	NT	NSpPP	NSePP	AGBY	GY	SY	HI	1000sw
IF (kg/ha)								
75	4.8a	9.71a	78.90a	86.34a	40.42a	45.92a	46.85a	24.13ab
50	3.8bc	8.8ab	71.01b	76.48b	36.23b	40.24b	47.43a	24.440a
25	4.1bb	8.27b	68.72b	70.39c	32.34c	38.05b	46.03a	23.77bc
0	3.4c	8.12b	69.18b	64.92d	31.45c	33.47c	48.19a	23.660c
SEM(±)	0.15	0.35	2.19	1.77	0.84	1.25	0.76	0.16
lsd $_{(0.05)}$	0.45	1.02	6.4	5.2	2.45	3.67	Ns	0.48
FYM (t/ha)								
9	4.0a	8.95a	75.13a	81.33a	38.47a	42.86a	47.44a	24.53
6	4.2a	8.92a	72.48ab	74.3b	35.31b	38.99b	47.65a	23.9b
0	3.8a	8.31a	68.24b	67.96c	31.45c	36.41b	46.26a	23.57b
SEM(±)	0.13	0.3	1.89	1.54	0.73	1.08	0.66	0.14
lsd $_{(0.05)}$	Ns	Ns	5.5	4.5	2.12	3.18	Ns	0.41

Means within the same column followed by the same letter do not differ significantly at the 5% level of significance. IF=inorganic fertilizers; FYM=farmyard manure; NT=Number of tillers per plant; NSpPP=Number of spikes per panicle; NSePP= Number of seeds per panicle; AGBY=above ground biomass yield; GY=Grain yield; SY=Straw yield; HI=Harvest index; 1000sw=thousand seed weight; t=ton

4.1.2.1 Number of Tillers (NT)

Number of tillers (NT) per plant varied significantly among the use of different levels of inorganic fertilizers but non-significantly among the use of organic sources. Number of tillers per plant was highly influenced by the effect of the inorganic fertilizers but not by the main effect of FYM. Higher average number of tillers per plant (i.e. 4.8) was recorded when inorganic fertilizers are applied at the higher level (75kg/ha), while the lowest number of tillers (3.4) per plant was also recorded with the main effect of the inorganic fertilizers when zero level was used. Although there was no significant difference among the different levels of FYM on the number of tillers, there was more number of tillers with all the levels of the FYM than the control (Table 6).

4.1.2.2 Number of Spikes per Panicle (NSpPP)

As Table 5 clearly depicts, number of spikes per panicle (NSpPP) was significantly affected by the different levels of the inorganic fertilizers as a main factor but no significant difference by the use of different levels of organic sources as a main factor. But when compared to the control plot, both of the main effects brought higher number of spikes per panicle. Number of spikes per panicle (NSpPP) for the main effect of the inorganic fertilizers ranged from 8.12 when no inorganic fertilizer (IF) is used to 9.71 when the highest level of this IF was used (75kg/ha). Although no significant difference, the same trend was true for the FYM, i.e. Number of spikes per panicle (NSpPP) increased when more level of FYM was used (Table 6).

4.1.2.3 Number of Seeds per Panicle (NSePP)

Number of seeds per panicle (NSePP) was significantly affected by the main factor effects of both FYM and inorganic fertilizers but not by their combined effects (Table 5). With regard to the FYM and IF 9 inorganic fertilizers as a main factor (Table 15), more number of seeds per panicle (78.9) were found for the inorganic fertilizers with the use of higher level (75kg/ha). On the other hand, the highest number of seeds per panicle for the organic sources is 75.13 kg/ha when 9t/ha of FYM is used. In both cases, the number of seeds per panicle increased for the increased level of the two nutrient source options. For the combined effect of the organic and inorganic sources, though no significant difference, higher number of seeds per panicle (81.87) was obtained when 75t/ha of FYM was used in conjunction with 75kg/ha of the inorganic fertilizers and the lowest value was obtained for the control (58.9) (Table 6).

4.1.2.4 above Ground Biomass Yield (BY)

The mean square table, the main factor effect and the combined factor effect of FYM and IF are depicted in Tables 7, 8 and 9. The results showed that all organic (FYM) and inorganic fertilizer (IF) treatments significantly ($P<0.05$) increased the biological yield of rice compared with the control treatment. For the main factor effects of inorganic fertilizers, the maximum biological yield of 86.34ql/ha was obtained in treatment receiving N/P from 75 kg/ha of DAP and Urea and for the FYM as a main factor the maximum AGBY was observed from the application of 9t/ha FYM which is 81.33Ql/ha.

As for the combined effects of organic and inorganic fertilizers, the biological yield was maximum (94.39 Ql/ha) for the treatment receiving 75kg/ha of IF in conjunction with 9t/ha of FYM. The minimum biological yield (54.91Ql/ha) was obtained in the control receiving no DAP/urea or FYM. These results indicated that the yield of biological mass (AGBY) was more in response to combined application of DAP + Urea and FYM. These findings are in agreement with Zahir and Ahmad (2006), who reported significant increases in wheat grain and straw yields with addition of FYM to inorganic fertilizers as compared to no FYM.

4.1.2.5 Straw Yield (SY)

The main and interaction effects of both the organic and inorganic sources of plant nutrients up on the grain and straw yield of the upland rice is shown in Tables 8 and 10 respectively. The straw yield of the upland rice varied from 30.64 Ql/ha (the control) to 49.99 Ql/ha where 9t/ha FYM is combined with 75kg/ha of inorganic fertilizer (Table 10). Generally, each and every treatment produced higher straw yield than the control. The highest straw yield 49.99Ql/ha was observed in treatment 6 i.e. when 9t/ha FYM is combined with 75kg/ha of the recommended dose of inorganic fertilizer, which was numerically higher than all other treatments though not statistically different. The lowest straw yield (30.64 Ql/ha) was obtained in first treatment (the control). When the effects of the main factors are considered, just like that of the grain yield, there is an increased straw yield when more level of either the organic or inorganic sources was used. When comparing the organic and inorganic sources as to their main effects, more average straw yield was obtained with the use of inorganic sources (Table 6). The combined effect of 75kg/ha of DAP and Urea with 9t/ha of the FYM gave the highest straw yield (49.99Ql/ha) which is 63.15% higher than the control (30.64Ql/ha) which is much higher than the percentage increase by the main effects of the inorganic fertilizers (49.87%) and the organic ones (39.9%) as a main factor. Therefore, the combined effect of organic and inorganic sources gave higher grain and straw increments than their respective main effects. These results indicated that under the given experimental conditions, combined application of FYM and DAP/Urea significantly improved straw yield of rice. Like the biological yield, this result agrees with the findings of Zahir and Ahmad (2006) who reported that Urea was indicated as a quick and more potent source of nitrogen for increasing the vegetative growth as compared to FYM but the combination of the two sources in was found more effective.

Table 7: Grain and straw Yield of rice (Ql/ha) as influenced by the main effects of organic and inorganic fertilizers at Maitsebri, Ethiopia, 2011/12.

Variable	Grain Yield (Ql/ha)	% over control	Straw Yield (Ql/ha)	% over control
IF (kg/ha)				
75	40.42a	66.5	45.92a	49.87
50	36.23b	49.3	40.24b	32.31
25	32.34c	33.3	38.99b	25.3
0	31.45c	29.6	33.4c	9
Abs.Control	24.27		30.64	
SEM(±)	0.725		1.25	
FYM (t/ha)				
9	38.47a	58.5	42.86a	39.9
6	35.31b	45.5	38.99b	27.3
0	31.55c	29.9	36.41b	18.3
Abs.Control	24.27		30.64	
SEM(±)	0.84		1.09	

Means within the same column followed by the same letter do not differ significantly at the 5% level of significance; IF= Inorganic fertilizer; FYM= farmyard manure; Ql/ha= quintal/ha

4.1.2.6 Grain Yield (GY)

The main effects of FYM and inorganic fertilizers (IF) as well as their interaction effects on grain yield of rice were depicted in Table 7 and Table 8 respectively. Analysis of variance showed significant ($p<0.05$) difference both for the main effects of organic and inorganic fertilizer on grain yield of rice. Each and every treatment produced significantly higher grain yield over the control. Whenever both organic and inorganic fertilizers were used, grain yield of rice increased significantly among all the treatments. As a main factor, the highest rate of the inorganic fertilizer (75kg/ha) produced significantly higher rice grain yield (40.42Ql/ha) than the other corresponding lower levels and the control (Table 7). Higher mean grain yield was obtained on the use of inorganic fertilizers while a relatively lower mean grain yield per hectare was recorded on the FYM (Table 8). This could be attributed due to the gradual decomposition and slow release of nutrients in FYM and its slow availability throughout the growing period of the crop (Daniel, 2006). The grain yield also increased significantly with increasing rates of FYM from 6t/ha to 9t/ha. Application of the different recommended rates of inorganic fertilizers along with different levels of organic manures (FYM) significantly increased grain yield when compared with plants that received no fertilization (the control).

As is depicted in Table 7, when compared with the application of the organic sources (FYM), the 75kg/ha of the recommended rate of inorganic fertilizer yielded 40.42Ql/ha and increased the grain yield by 66.5% over the control (24.7Ql/ha) while the 75kg/ha of the dose of this rate when combined with 9t/ha of the FYM resulted (44.4Ql/ha) and resulted in 82% increase of grain yield over the control (24.7Ql/ha). This confirms with the finding of Daniel (2006) which has showed integration of organic fertilizers with inorganic fertilizers has improved the yields of potato and more than their main effects. The result, therefore, clearly showed that the yield of rice could be maximized by the combined application of organic and inorganic fertilizer.

All integrations of the 75%, 50% and 25% of the recommended doses of inorganic fertilizers along with all rates of the organic sources were also superior to the unfertilized plot (Table 8). The increase in the grain yield of rice with combined application of FYM with the different rates of inorganic fertilizers could be attributed to their favorable effects on the other yield components such as average number of tillers per plant, plant height, panicle length and dry matter production. This results agree with the findings of Sanchez and Jama (2000) who reported that integration of organic and inorganic inputs increase and sustains crop production due to their positive interactions and complementarities between them. Bodruzzaman (2010), also concluded that the crop yields and nutrient availability were higher in plots applied with FYM than the non-applied ones indicating that Organic manures (like the FYM) were more effective in producing higher crop yields and providing nutrients because of their higher nutrient content than the inorganic fertilizers. From the above results, it may be concluded that the combined use of FYM and IF was the most suitable for both improving soil properties and increasing crop yields in rice production systems.

4.1.2.7 Thousand Seed Weight (1000SW)

Manure, inorganic fertilizers as well as their interactions significantly influenced the 1000 seed weight of rice as is presented in Table 10. There was highly significant ($p<0.01$) influence of the different levels of organic and inorganic fertilizer as a main factor and significant ($p<0.05$) interaction effect by the application of organic manures and inorganic fertilizer levels on 1000 seed weight (Table 10). These effects are typically represented by grain yield and straw yield data which shows that application of farmyard manure (9t/ha) in combination with inorganic fertilizers of level (75kg/ha) produced an optimum grain yield when compared to other treatment combinations (Table 8). This result agrees with the findings of Fageria *et al.*, (2011) who indicated that integrated use of organic and inorganic sources of plant nutrients significantly improved yield of rice by improving the yield components like panicle number, thousand grain weight, grain harvest index, plant height and reduced grain sterility which are positively and directly associated with grain yield.

4.1.2.8 Harvest Index (HI)

The effect of different sources of organic and inorganic fertilizers on the harvest index of upland rice is indicated in Table 8. FYM and inorganic fertilizer application as well as their interactions did not significantly affected the harvest index of the upland rice (Table 10).The reason is that as the application rate of both the organic and inorganic sources of fertilizers increase, both the grain yield and the above ground biomass yield also increase which directly makes no or little change on the ratio of the grain yield to the above ground biomass yield which is the harvest index. This agrees with the findings of Zelalem et al.(2009) where increasing the levels of nitrogen (N) and phosphorous (P) fertilizers as well as their interactions didn’t brought any significant influence on the harvest index of potato which is a highly nutrient feeder crop just like that of rice.

Table 8: Yield and Yield parameters of upland rice as influenced by the integrated nutrient management, at Maitsebri, Ethiopia.

Trts	Combinations		NSpPP	NSePP	NT	BY	SY	GY	HI	TSW
	FYM (t/ha)	IF (kg/ha)								
Trt1	**0**	**0**	7.167c	55.63	3.000c	54.91	30.64	24.27f	44.15	23.03f
Trt2	**0**	**75**	9.33	76.9	4.600a	82.04	43.94	38.11b	46.5	24de
Trt3	**0**	**50**	8.3	68.27	3.80abc	71.38	36.8	34.6bcd	48.42	24.57cd
Trt4	**0**	**25**	8.4	64.93	3.667bc	63.51	34.26	29.25e	45.92	23.47ef
Trt5	**9**	**0**	8.7	71.77	3.667bc	73.13	36.5	36.66bc	50.17	24.63bcd
Trt6	**9**	**75**	9.67	87.07	4.667a	94.39	49.9	44.40a	47.1	26.23a
Trt7	**9**	**50**	9.3	65	3.600bc	78.19	41.2	37.01bc	47.4	25.27bc
Trt8	**9**	**25**	8.37	68.7	4.133ab	79.61	43.8	35.8bcd	45.1	25.47ab
Trt9	**6**	**0**	8.5	75.7	3.667bc	66.72	33.3	33.4cde	50.2	24.13de
Trt10	**6**	**75**	10.13	87.5	4.667a	82.58	43.8	38.74b	46.9	24.07de
Trt11	**6**	**50**	8.9	77.9	4.000ab	79.86	42.7	37.11bc	46.5	24.47cd
Trt12	**6**	**25**	8.13	67.6	4.333ab	68.05	36.0	31.97de	46.9	24.13de
	CV (%)		11.99	11.39	13.52	7.14	9.53	7.15	4.88	2.17
	$LSD_{(0.05)}$		1.772	13.93	0.912	9.007	6.362	4.251	3.89	0.898
	SEM(±)		1.095	67.70	0.29	28.291	14.111	6.307	5.278	0.281

Key: *Means within the same column followed by the same letter or by no letters do not differ significantly at the 5 % level of the lsd test. IF=inorganic fertilizers; M=farmyard manure; NT=Number of tillers per plant; NSpPP=Number of spikes per panicle; NSePP= Number of seeds per panicle; AGBY=above ground biomass yield; GY=Grain yield; SY=Straw yield; HI=Harvest index; TSW=thousand seed weight; df=degrees of freedom*

5 .CONCLUSIONS AND RECOMMENDATIONS

Rice was found to respond significantly to the combined effects of FYM and inorganic fertilizers for the majority of the agronomic parameters too. Greater number of days (122.5) to physiological maturity was recorded when higher dose (9t/ha) of FYM was used. The application of the highest dose (75kg/ha) of inorganic fertilizers alone significantly reduced the days to maturity as compared to the organic sources which resulted in longest days to maturity (122.5 days). Although the interaction effect of inorganic fertilizers and FYM on the final plant height was not statistically significant, highest plant height was recorded when 9t/ha of FYM is used in conjunction with 75kg/ha DAP and 75kg/ha of Urea. Higher mean grain yield was obtained on the use of inorganic fertilizers as a main factor while a relatively lower mean grain yield per hectare was recorded on the FYM as a main factor. This could be attributed to the gradual decomposition and slow release of nutrients in FYM applied treatments and its slow availability throughout the growing period of the crop. Highest mean grain yield of 44.4 Ql/ha was found from the combined application of both organic and inorganic fertilizers at the higher rates. These results showed that yield of rice could be maximized by the combined application of organic and inorganic fertilizer. From the agronomic point of view, it was apparent from the above results that 9 t/ha of FYM in conjunction with 75kg/ha of each DAP and Urea yielded better than the rest of the treatment combinations which is 44.4Ql/ha. Combined use of FYM with inorganic fertilizers not only increases the rice yield but also improved the fertility status of the soil, and could save part of the money that would have been paid for the greater doses of the chemical fertilizer and is socially acceptable. This is one year result. However, the capacity of FYM in leaving a significant residual nutrient effect on the succeeding crops needs further long-term research because nutrient is residually accumulated each year. Such studies need to be conducted at various soil and agro-climatic conditions to generate more reliable information.

6. ACKNOWLEDGMENT

My heartfelt thanks go to the agricultural experts, development agents and all the respected farmers of my study area without whom it would be difficult to understand agriculture in reality; and SIDA for its financial support for this research.

7. CONFLICT OF INTEREST

–The authors have no conflict of interest.

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