International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print)
Vol. 2, No. 9, p. 14-32, 2012
http://www.innspub.net

RESEARCH PAPER

OPEN ACCESS

Effects of nitrogen sources and application time on yield attributes, yield and grain protein of rain-fed NERICA-3 rice in Gambella, Ethiopia

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

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

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

[3]*Department of Plant Sciences, Haramaya University, P. O. Box 138, Dire Dawa, Ethiopia*

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

Received: 06 August 2012
Revised: 16 August 2012
Accepted: 17 August 2012

Key words: Application time, NERICA-3 rice, nitrogen sources, partial budget, yield, yield attributes.

Abstract

A field experiment was carried out under rain-fed conditions at *Imla,* Gambella Agricultural Research Institute in 2008 and 2009 main cropping seasons in order to compare the effects of N sources [ammonium nitrate (NH_4NO_3), ammonium sulfate ($(NH_4)_2SO_4$) and urea ($CO(NH_2)_2$)] and their time of application (½ at sowing + ½ at tillering; ⅓ at sowing + ⅓ at tillering + ⅓ at panicle initiation; ½ at sowing + ½ at panicle initiation, and ½ at tillering + ½ at panicle initiation) on growth, yield attributes and yield of rice (*Oryza sativa* L.) variety NERICA-3 (*O. sativa x O. glaberrima*), in a factorial experiment laid out in a RCBD replicated thrice. Nitrogen from each source was applied at the rate of 92 kg N ha^{-1}, and the plots received uniform dose of 46 kg P and 20 kg K ha^{-1} at sowing. The results revealed that effects of year on rice days to flowering, panicle length, number of grains and grain weight $panicle^{-1}$, grain yield, grain protein content ($P \leq 0.01$), plant height, and straw yield ($P \leq 0.05$) were only significant. The responses of rice growth and yield components and grain protein to sources of N were not significant ($P > 0.05$). Plant height, panicle length and grain weight $panicle^{-1}$ to application time were significant ($P \leq 0.05$) while the other growth and yield components and grain protein were not ($P > 0.05$). Only grain and straw yield significantly ($P \leq 0.01$) influenced by interaction of N sources and application time whereas the other yield and growth components and grain protein not ($P > 0.05$). Effects of sources of N, interactions of year by sources of N, year by application time and year by sources of N by application time were insignificant($P > 0.05$) on the rice growth, yield components and grain protein. Significantly increased rice grain yield (6.33 t ha^{-1}) obtained with NH_4NO_3 applied ½ at sowing + ½ at tillering. The, results were subjected to economic analysis using the partial budget procedure to determine sources of N and application time that would give acceptable returns to farmers. Economic analysis showed that $CO(NH_2)_2$ applied ½ at sowing + ½ at panicle initiation and ½ at tillering + ½ at panicle initiation are superior and stable within a price variability range of 15%. Hence, it may be recommended for production of NERICA-3 rice under the climatic conditions prevailing in the study area.

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

Introduction

Rice (*O. sativa* L.), family *Poaceae*, subfamily *Oryzoideae* and tribe *Oriyzeae,* is one of the most important cereal crops of the world grown in a wide range of climatic zones. There are about 25 species (annual and perennial) of *Oryza*, of which only two species (O. sativa Linus and *O. glaberrima* Stead) are cultivated (Reddy, 2006; Astewel, 2010). The former is originated in North Eastern India to Southern China but has spread to all parts of the world. The latter is still confined to its original home land, West Africa. According to Brohi *et al.* (1998), rice is the most important food crop of half of the human race, whereas Roy *et al.* (2011) reported that it is one of the main staple foods for nearly two-thirds of the population of the world. Cultivated rice, both Asiatic and African, are an annual grass with culms terminated by a loose panicle inflorescence having single perfect flowered spikelet (Reddy, 2006).

Africa produced an average of 21.9 million tons (t) of rough rice in the year 2006 on 9.2 million hectare (ha) of land equivalent to 2.5 and 6.0% of the world total production and rice area, respectively. By world standards, Africa is a minor player as far as rice production is concerned. The people consume more rice than what is produced on the continent. During the 2001-2003, milled rice production in Africa averaged 11.80 million t per annum, whereas, consumption averaged 15.27 million t of milled rice per year, of which 5.24 million t (22.72%) is imported (FARA, 2009).

The economy of Ethiopia is largely dependent on agriculture. Crop production is estimated to contribute on average about 60% of the total agricultural value (Astewel, 2010). Ethiopia is emerging as an important rice growing country in Eastern Africa. The area under rice production in Ethiopia is estimated to have increased from 49,948 ha in 2007 to about 155,886 ha in the 2009. Owing to its recent introduction to the country, the research and development effort so far undertaken on rice in Ethiopia is of limited scale. However, its productivity, varied uses, existence of vast suitable conditions (swampy, water-logged, rain-fed and irrigable land) and possibilities of growing it where other food crops do not perform well make rice among the promising alternative crops available for cultivation in Ethiopia. As a result, rice among the target commodities of the millennium development of the country which is named “Millennium crop” as it is expected to contribute greatly towards ensuring household as well as national food security in the country

Introduction of hybrid rice is an important step towards augmentation of rice yield. Hybrid rice yields about 15-20% more than the promising high yielding commercial varieties (Chaturvedi, 2005). In order to increase rice production and quality related to its genetic potential, use of judicious nitrogen (N) source and application time are among the most important agronomic practices (Manzoor *et al.,* 2006). Nitrogen application time is the major agronomic practice that affects the growth, yield and quality of rice crop which is required as much as possible at early and mid tillering stages to maximize panicle number and during reproductive stage to produce optimum filled spikelets panicle^{-1} (Sathiya and Ramesh, 2009). The efficient utilization of N helps in reducing the cost of production and producing high yields with low inputs of N (Limon-Ortega *et al.,* 2000).

Given the importance of N fertilization on the yield in grain from the rice plant, it is necessary to know what the best source, level and application time is for each variety as well as its influence on components of yield and other agronomic parameters such as the plant height, LAI, lodging, days to flowering, number of tillers m^{-2} and moisture content of the grain, in order to obtain better knowledge of said productive response (Chaturvedi, 2005; Manzoor *et al.,* 2006; Salem, 2006; Jan *et al.,* 2010). Nitrogen fertilizer sources, levels and application time had significant roles in determining uptake of fertilizer and its partition to soil and plant (Iqbal *et al.*, 2005; Kichey *et al.*, 2007; Jan *et al.,* 2010). As a result, the type of nitrogenous fertilizer also affects the yield and quality of the grain. Fertilizers like $CO(NH_2)_2$ are substantially cheaper than others and their use may be justified on economic grounds provided as they do not adversely affect the yield or quality of the grain (Chaturvedi, 2005). According to Assefa *et al.* (2009), di-ammonium phosphate could be chosen as an appropriate inorganic N fertilizer source followed by $(NH_4)_2SO_4$ for better grain yield of rice; the latter suggested that there may be a need to fertilize rice with sulfur containing fertilizers.

On the other hand, Jensen (2006) suggested that all sources/forms of N fertilizer can perform equally well to aid in crop production if applied as long as consideration of the movement and loss mechanisms inherent in the N cycle are understood and management of specific fertilizer is appropriate as far as timing, based on plant need, soil type and placement is concerned. Highest yield response to applied N, in general, varies from 40-60 kg ha^{-1} in fertile soils of delta areas to 80-100 kg ha^{-1} in light soils of low fertility during the main rainy season. In dry season, optimum rate of application, in general, is 100 and 120 kg N ha^{-1} for short and medium, and for long duration rice varieties, respectively (Reddy, 2006). Manzoor *et al.* (2006) applied 100/50/50 kg N/P/K ha^{-1} and found that N applied ½ at 50% tillering + ½ at panicle initiation gave maximum yield attributes and yield followed with ½ at transplanting + ½ at panicle initiation with respect to height, productive tillers, panicle length and grains panicle^{-1}. Recommended dose of N at pre-sowing and tillering or transplanting and tillering (Biloni and Bocchi, 2003.); tillering and panicle initiation (Raza *et al*., 2003); sowing, tillering and panicle initiation (Krishnan and Nayak, 2000) and transplanting, tillering and panicle initiation (Raza *et al*., 2003; Kenzo, 2004) significantly increased growth parameters, yield attributes and yield of rice.

Timing of N application had a significant role on reducing N losses, increasing N use efficiency and avoiding unnecessary vegetative growth (Jan *et al*., 2010). When N was applied before the onset of stem elongation (Mossedaq and Smith, 1994) and at that first node stage (Limon-Ortega *et al.,* 2000), the total N uptake was greater than at planting time. Similarly, Tran and Tremblay (2000) reported that early application of N at planting and tillering had lower N fertilizer uptake than later application (shooting) in wheat. Further, fertilizer recovery was higher when N was applied at anthesis compared to at planting (Wuest and Cassman, 1992). Pan *et al.* (2006) reported that during grain filling, N remobilization from the leaves, stem and chaff depended on the curvilinear or linear decrease of the N concentration.

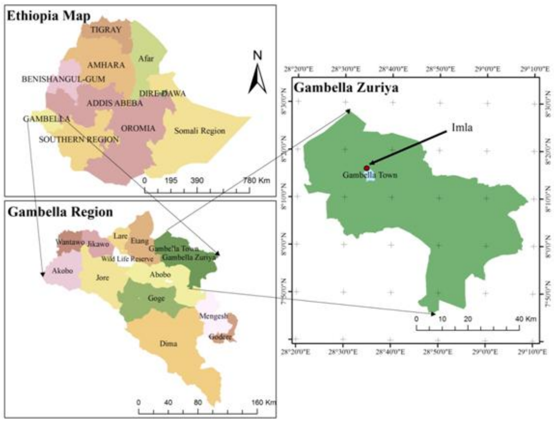

Fig. 1. Location map of the study area, Imla, nearby Gambella town in Gambella Zuria District.

In addition, altering the split doses according to the crop requirement also needs to be analyzed under rain-fed rice cultivation. Thus, optimization of N sources as well as time of application at different growth stages is more important to produce higher rice grain yield. Considering this fact, this investigation was undertaken during the rainy seasons of the 2008 and 2009 to have a detailed account of the effects of three commercially available nitrogenous fertilizers and their time of application on rice growth, yield attributes, yield, grain quality and economic viability of the treatment under the agro-climatic conditions prevailing at the *Imla* site of Gambella Region, Ethiopia.

Materials and methods

The study site

An experiment, to determine the effects of sources and timing of N application on growth, yield attributes and yield on rain-fed rice, was carried out at *Imla*, Gambella Agricultural Research Institute, Gambella, Ethiopia, during the main rainy seasons of the 2008 and 2009. The site is geographically located at 8 ° 14' 46.36" N latitude and 34 ° 35' 17.75" E longitude (Wikipedia, 2011), and at an altitude of 450 meters above sea level (Figure 4.1).

The area is characterized by hot-humid tropical lowland climate. This area`s long year total annual rainfall was 1227.55 mm. The average yearly minimum and maximum temperatures were 19.9 and 35.5 °C, respectively (NMA, 2009). The total rainfall during the two cropping seasons was 816.9 and 403.1 mm while the mean maximum and minimum temperatures were 32.4, 34.1 °C and 21.3, 22.0 °C in 2008 and 2009, respectively (Figure 4.2).

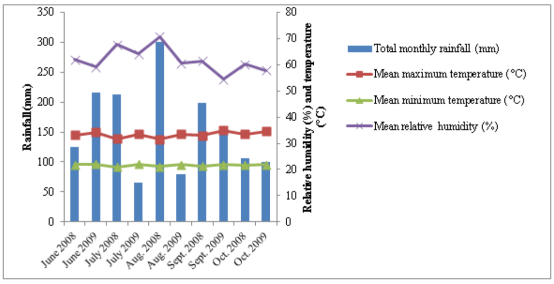

Fig. 2. Monthly weather data for the 2008 and 2009 cropping seasons (Source: Gambella Meteorological Service Branch Office).

The soil of the experimental field was clay in texture consisting 4.08% organic carbon, 0.51% total N, 650.00 mg kg^{-1} available P, 0.60 cmol$_c$ kg^{-1} available K, 6.3 mg kg^{-1} sulfur and having a pH of 6.43 (Table 1). The dominant soil at and around the study site was brownish clay.

The treatments comprised of three sources of N [ammonium nitrate (NH_4NO_3), ammonium sulfate ($(NH_4)_2SO_4$) and urea (CO $(NH_2)_2$] and their split application (½ at sowing + ½ at tillering; ⅓ at sowing + ⅓ at tillering + ⅓ at panicle initiation; ½ at sowing + ½ at panicle initiation and ½ at tillering + ½ at panicle initiation) arranged in factorial combination in a randomized complete block design with three replications. The N composition of the ammonium nitrate (NH_4NO_3) and urea (CO $(NH_2)_2$) were 34 and 46%, respectively, while ammonium sulfate ($(NH_4)_2SO_4$) consisted of 21% N and 24% S.

Table 1. Physiochemical properties of the experimental soil before sowing and after harvest of rice in 2008 and 2009 crop seasons.

Soil analysis	BS (2008)	AH (2008)	AH (2009)
Sand (%)	17.68	-	-
Silt (%)	32.72	-	-
Clay (%)	49.60	-	-
Soil texture	Clay	-	-
pH	6.43	6.80	6.20
Organic carbon (%)	4.08	1.40	2.70
Total N (%)	0.51	0.15	0.29
Available P (mg kg^{-1})	650.00	751.16	448.02
Available K (cmol$_c$ kg^{-1})	0.60	0.66	0.32
S (mg kg^{-1})	6.30	5.95	13.70

BS = Before sowing; AH = After harvesting; pH = The negative logarithm of the hydrogen ion activity of a soil [-log (H^+)

Experimental treatments, design and procedures

The field was plowed using tractor in April 2008. Disking, harrowing and leveling were done to prepare a suitable seed bed to get proper germination and root development. The experiment was conducted on a fixed layout with plot size of 4 x 4 m (16 m^2). To control mixing of treatments, experimental plots were prepared manually in the second season. The outer most row and 0.5 m row length at both ends of plots were considered as borders. The second, third and fourth rows on both sides of plots were designated for destructive sampling, non destructive sampling and guard rows, respectively. Thus, the net plot size was 3.0 m x 2.4 m (7.2 m^2).

An upland rice variety, NERICA-3, was used as planting material. Since germination percentage expresses the proportion of the total number of seeds that are viable, it was determined through control test using news paper (absorbent material), water proof tray, randomly sampled mixed rice seed lot and water for 10 days. Each day was checked that news paper remains moist and recorded the actual counts of the number of germinated seeds. Germination (%) was calculated as the ratio of number of seeds germinated to number of seeds placed on the tray multiplied by 100 and recorded as 96.1% in 2008 and 94.8% in 2009.

The seeds were drilled manually at the rate of 100 kg ha^{-1} in rows 20 cm apart in the last week of July each year. Nitrogen (92 kg ha^{-1}) was applied from each source as per the treatments as urea, whereas the entire doses of P (46) and K (20) in kg ha^{-1} were applied at sowing in the form of triple super phosphate and potassium chloride, respectively. Recommended agronomic practices were uniformly followed to raise the crop. Finally, the crop was harvested in the second week of October each year.

Soil sampling and analysis

Composite surface (0-30 cm depth) soil samples (one composite sample per block) were collected with a gauge auger in the 2008 before plowing the experimental field and blocking it into three depending on land uniformity. Plant residues on the soil surface were removed prior to sampling and 8 soil sub-samples for a composite surface soil sample per block were collected for characterization of selected soil physicochemical properties (Table 1). Accordingly, the samples were analyzed for soil texture following the hydrometer method (Jackson, 1967). Soil pH was determined in a 1:2.5 soil-water suspension using a combination of glass electrode. Organic carbon (OC) was estimated by the wet digestion method (Okalebo *et al.*, 2002).

Exchangeable K was extracted with 1 M ammonium acetate solution adjusted to pH 7.0 (Sahlemedhin and Taye, 2000). From the extract, exchangeable K was analyzed using flame photometer (Black, 1965). Further, sulfur (S) was extracted with $Ca(H_2PO_4)$ in $2NH_4OAc$ and measured turbidmetrically (Hoeft *et al.*, 1973). Total soil N was measured using the micro-Kjeldahl digestion, distillation and titration procedure as described by AOAC (1994). After extraction of soil sample by sodium bicarbonate solution as per the procedure outlined by Olsen *et al.* (1954), available P was determined by measuring the absorbance using spectrophotometer at a wave length of 880 µm.

Crop agronomic and yield data collection

The observations on growth and yield attributes were made on randomly sampled plants per plot. Days to flowering was recorded by visual observation from the net plot. Leaf area index (LAI) was recorded using the length-width method (Reddy, 2006) during panicle initiation using 0.725 adjustment factor (Tsunoda, 1964).

The productive tillers were counted during physiological maturity from 1.5 m row length of non destructive rows found at both sides of each net plot. Plant height (cm) was measured from the base of the plant to the tip of panicle during physiological maturity from randomly sampled 25 plants per plot. Whereas panicle length, grain number $panicle^{-1}$ and grain weight $panicle^{-1}$ were recorded from 20 randomly selected plants per plot. Similarly, 1000-grain weight was recorded by taking the weight of 1000-grains per plot using sensitive balance. Grain and straw yield were recorded from net plot area. After threshing and winnowing, the grain was sun dried and their weight was recorded after adjusted at 14% grain moisture content while the straw was obtained as the difference of the grain yield from the total above ground biomass. The N content of the rice grain was analyzed from the respective grain sample collected treatment wise using the micro-Kjeldahl digestion, distillation and titration procedure as described by AOAC (1994). The grain protein content (N x 6.25) was also determined according to the AOAC (1994).

Statistical analysis

Data were statistically evaluated using a two-way ANOVA following the General Linear Model procedure of the Statistical Analysis System (SAS) processing package, version 9.10 (SAS, 2003). When significant differences were observed, comparisons of means were performed using the Duncan Multiple Range Test at 5% probability level.

Economic analysis

Economic viability evaluation was done using partial budget with dominance, marginal and sensitivity analysis as described in CIMMYT (1988). Partial budget is a way of calculating total cost that varied (TCV) and the net benefits (NB) of each treatment in an on farm experiment. It includes adjusted grain yield and gross field benefits (GFB). The adjusted yield for a treatment was the average grain yield adjusted downward to a certain percentage (30% in our study) to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment without the involvement of researchers (Shah *et al.*, 2009)

To estimate the economic parameters, products were valued based on local market price collected during May 2009 where rice was 4.0 Ethiopian Birr (ETB) kg^{-1}. Costs related to N source in ETB per 100 kg at the time of the experiment were 300 [$CO(NH_2)_2$], 600 [$(NH_4)_2SO_4$], 550 (NH_4NO_3), 37.5 (transport cost) and 50 (application cost ha^{-1}).The transport cost of fertilizer was estimated from market to farm entry. The farm entry price of rice was assumed to be the retail price in village markets during the period. Some of the concepts used in the partial budget analysis were GFB, TCV and the NB. The GFB ha^{-1} was obtained as the products of real farmers' price and the average rice grain yield for each treatment. The TCV in the partial budget analysis referred to the sum of costs of fertilizer, transport, labor and credit (interest paid at 6% on total cost that vary), whereas the NB ha^{-1} was the difference between the GFB and the TCV. The dominance analysis procedure, which was used to select potentially profitable treatments, comprised ranking of treatments in order of ascending order. Total cost that varied from the lowest to the highest cost to avoid those treatments costing more but producing a lower NB than the next least cost treatment. The selected and discarded treatments by using this technique were referred to as undominated and dominated treatments, respectively. For each pair of ranked undominated treatments, a marginal rate of return (% MRR) was calculated. The % MRR between any pair of undominated treatments denotes the return per unit of investment in crop managing practices expressed as %age. The % MRR is given by the equation: % MRR = Change in net benefit (ΔNB)/Change in total cost that varies (ΔTCV) x 100.

In order to make recommendations from marginal analysis, it is vital to approximate the least acceptable rate of return to farmers in the advice domain. Experimental evidences have shown that for majority of situations, acceptable MRR will be between 50 to 100%. For most of the cases, when there is preamble of any new input, 100% is suggested and was used for analysis in this study**.** To confirm the results obtained were within the framework of farm level and market suspicions, sensitivity test under worst situations was carried out, where input or output market price rise or fall by 15% was considered.

Results and discussion

Effects of n sources and application time on growth characters of rice

All the growth and yield parameters (Tables 2, 3 and 4) and grain protein content (Table 4) were insignificantly ($P > 0.05$) affected by application of sources of N fertilizers. Our findings were in harmony with the Jensen (2006) suggestion that all forms of N fertilizers can perform equally well if applied appropriately to aid in crop production.

Table 2. Combined analysis of variance showing the effects of sources of N and application time on growth, yield attributes and grain protein of rice in 2008 and 2009.

Parameter	Mean square for source of variation							
	Year (1)	SN (2)	AT (3)	Y x SN (2)	Y x AT (3)	SN x AT (6)	Y x SN x AT (6)	Error (44)
Growth parameters								
Days to flowering	1760.22**	1.56	2.87	1.56	9.56	1.87	1.83	4.95
Leaf area index	0.02	0.17	0.03	0.11	0.05	0.06	0.06	0.08
Plant height (cm)	176.41*	2.83	181.89*	8.13	55.31	94.50	34.86	43.22
Yield attributes and yield								
Number of tillers m^{-2} (No	8146.62	2754.97	837.44	2619.59	3270.62	584.67	2060.11	2863.50
Panicle length (cm)	201.14**	0.81	3.38*	0.36	0.82	0.98	1.69	0.96
Number of grains $panicle^{-1}$	15658.60**	628.94	1036.77	613.93	362.11	310.08	699.30	507.62
Grain weight $panicle^{-1}$ (g)	7.04**	0.43	0.80*	0.14	0.08	0.22	0.22	0.26
1000-grain weight (g)	0.59	0.85	1.95	1.86	1.58	3.92	6.14	3.04
Grain yield (t ha^{-1})	50.05**	0.24	1.07	1.80	1.25	3.71*	1.10	1.37
Straw yield (t ha^{-1})	39.15*	4.45	4.67	2.65	1.58	10.64*	3.38	3.86
Grain quality								
Grain protein (%)	387.49**	19.67	2.95	25.41	14.43	28.18	22.50	13.19

SN = sources of N; Figures in parenthesis = Degrees of freedom; AT = Application time; Y = Year; ** = Significant at P = 0.01; * = Significant at P = 0.05; t = Ton; ha = Hectare

Table 3. The main effects of year, N sources and application time on days to flowering, leaf area index, plant height, number of tillers per m2 and panicle length of rice.

N sources	Days to flowering	Leaf area index	Plant height (cm)	No. of tillers m^{-2}	Panicle length (cm)
Year					
2008	69.08b	0.95	104.98a	146.36	20.60b
2009	72.97a	0.98	101.85b	167.63	23.94a
NH_4NO_3	74.08	0.88	103.74	163.81	22.22
$(NH_4)_2SO_4$	73.75	1.05	103.45	162.53	22.11
$CO(NH_2)_2$	74.25	0.96	103.06	144.64	22.47
Application time (AT)					
AT_1	73.78	0.90	106.29a	155.51	22.89a
AT_2	73.67	0.97	105.89a	162.82	22.16ab
AT_3	74.56	0.98	99.84b	147.96	22.15ab
AT_4	74.11	1.00	101.65ab	161.67	21.87b
CV (%)	3.00	30.01	6.36	34.09	4.40

Means of the same factor in a column followed by the same letter are not significantly different at P > 0.05 by Duncan's multiple range test; AT_1 = ½ at sowing + ½ at tillering; AT_2 = ⅓ at sowing + ⅓ at tillering + ⅓ at panicle initiation; AT_3 = ½ at sowing + ½ at panicle initiation; AT_4 = ½ at tillering + ½ at panicle initiation; CV = Coefficient of variation

Days to flowering

There was a significant ($P \leq 0.01$) difference in days to flowering of rice between the means of experimental years. Main effects of sources of N, application time, interactions of year by sources of N, year by application time, sources of N by application time and year by sources of N by application time on days to flowering however, were not significant ($P > 0.05$) (Table 2). Days to flowering of rice delayed during 2009 than that of 2008 may be resulted from meteorological changes between the experimental years (Figure 4.2). For example, Kabuye and Drew (2000) reported that any drought that occurs after seedling germination to maximum tillering period will reduce the number of tillers and prolong the rice maturity period by a number of days (7-14 days). On the other hand, application of N sources and timing had no significant ($P > 0.05$) effect on days to flowering although days to flowering tended to increase from 73.75 to 74.25 and 73.67 to 74.56 days, respectively (Table 3). Maximum days to flowering (74.25 and 74.56 days) were obtained with application of CO $(NH_2)_2$ and application time of sources of N ½ each at sowing and panicle initiation, respectively.

This fact indicated that when N was applied before the onset of stem elongation and at first node stage, the total N uptake was greater (Mossedaq and Smith, 1994). Accordingly, accelerated root (efficient uptake of nutrients and water) and vegetative (efficient photosynthesis) growth might be a factor for resisting drought that delayed flowering and crop maturity (Haque *et al.*, 2006).

Leaf area index

The effects of different N sources, application time, interactions of experimental year with sources of N or application time, sources of N with application time and experimental year with sources of N and application time on the rice leaf area index was not significant ($P > 0.05$) (Table 2). In main effect, however, $(NH_4)_2SO_4$ showed higher leaf area index (1.05) followed by CO $(NH_2)_2$ (0.96) whereas NH_4NO_3 obtained the lowest (0.88) (Table 3) in an acidic soil of experimental site. Kushwaha *et al.* (1992) believe that lower N volatilization and denitrification from $(NH_4)_2SO_4$ is responsible for a higher leaf area in rice treated with this fertilizer. But TNAU (2008) reported that $(NH_4)_2SO_4$ fertilizer is not effective in acid soils and rice did not absorb N in nitrate form since the ammonium ions are readily absorbed on the colloidal complex of the soil. Whereas, Reddy (2006) reported that application of N in the form of nitrates in the early stages of growth may not have any effect since nitrates are easily leached or may prove even deleterious to the plant due to conversion of nitrate to nitrite.

In the case of application time, application of fertilizers ½ at tillering + ½ at panicle initiation produced highest leaf area index followed by ½ at sowing + ½ at panicle initiation (Table 3). The lowest was observed with application of fertilizers ½ at sowing + ½ at tillering followed by ⅓ at sowing + ⅓ at tillering + ⅓ at panicle initiation.

Plant height

Experimental year and time of N application had a significant ($P \leq 0.01$) effect on plant height. Rice plant height, however, did not show significant ($P > 0.05$) differences with sources of N, interactions of year by sources of N, year by application time, sources of N by application time and year by sources of N by application time (Table 2). Contrarily to this study, Assefa *et al.* (2009) found significant effect on rice plant height using urea, ammonium nitrate, ammonium sulfate, di-ammonium phosphate and calcium ammonium nitrate each at 120 kg N ha^{-1} as a source of N in the hot-humid North-western part of Ethiopia.

The average rice plant height was 104.98 and 101.85 cm in 2008 and 2009, respectively (Table 3). Even though not significantly affected by sources of N, the plants in NH_4NO_3 treated plots attained the maximum height (103.74 cm) followed by $(NH_4)_2SO_4$ (103.45 cm). The higher plant height obtained with NH_4NO_3 or $(NH_4)_2SO_4$ might probably be due to slow N release from these fertilizers, that supplies enough N in a pattern to satisfy the rice N requirement based on its physiological stages (Kiran and Patra, 2002). Moreover, the sulfur in $(NH_4)_2SO_4$ and its vital role in rice nutrition cannot be ignored; the higher plant height was obtained from ammonium sulfate, compared to $CO (NH_2)_2$. It has been reported that N losses from urea are extensive and much greater than ammonium nitrate or sulfate (Marschner, 1995) which might have led to higher plant height with ammonium nitrate or sulfate compared to $CO (NH_2)_2$ that obtained shortest rice plant height (103.06 cm). Chaturvedi (2005) also obtained decreased rice plant height in plots where $CO(NH_2)_2$ applied compared to calcium ammonium nitrate, super net(25.5% N and 9.8% S), ammonium sulfate nitrate and 20-10-12 NPK compound.

Plant height reveals the overall vegetative growth of the crop in response to various management practices (Chaturvedi, 2005). It was found that N application time significantly affected the rice plant height. The maximum plant height (106.29 cm) was obtained when the N was applied ½ at sowing + ½ at tillering, which had no statistical variation compared to height recorded with ⅓ at sowing + ⅓ at tillering + ⅓ at panicle initiation and ½ at tillering + ½ at panicle initiation (Table 3). Similarly no significant difference in plant height obtained between the N applied ½ at sowing + ½ at panicle initiation and ½ at tillering + ½ at panicle initiation.

Visual field observation of this study realized that application of $CO(NH_2)_2$, ½ at sowing + ½ at tillering, ⅓ at sowing + ⅓ at tillering + ⅓ at panicle initiation and NH_4NO_3 ½ at sowing + ½ at tillering tolerated water stress caused by interrupted rainfall than the rest of the application times in hot-humid lowland conditions of Gambella.

According to Abd El-Maksoud (2008), early application of N fertilizer favored plant height and this was seen when two splits gave the taller plants than three splits. The increase in plant height in response to application of N fertilizer was probably due to enhanced availability of N which resulted in more leaf area (Mandal *et al.*, 1992) that in turn enhanced photo assimilates and thereby resulted in more dry matter accumulation (Rupp and Hubner, 1995).

Effects of n sources and application time on yield attributes and yield of rice

Number of effective tillers:

The effects of experimental years, N sources, application time and their interactions on the number of effective tillers m^{-2} were insignificant ($P > 0.05$). Although not significant, higher number of effective tillers was recorded in 2009 cropping year that might be related to meteorological conditions with high solar radiation and sufficient supply of N (Haque *et al.*, 2006). Yield and yield attributes of rice cultivars are not only influenced by sources of N fertilizers, but also by their split application (Abd El-Maksoud, 2008). However, in this study like plant height, the number of tillers though not significant, varied between 144.64 m^{-2} [$CO (NH_2)_2$] and 163.81 m^{-2} (NH_4NO_3). In case of application time, N applied ⅓ each at sowing, tillering and panicle initiation resulted in more number of tillers followed by two equal splits at tillering and panicle initiation stages (Table 3) The present finding support the results of Jensen (2006) and Madan and Munjal (2009) who suggested that seed rate governs the number of tillers $plant^{-1}$ and all forms of N fertilizers can perform equally well if applied appropriately.

Panicle length:

The panicle length varied significantly due to the effects of cropping year ($P \leq 0.01$) and the application time of N sources ($P \leq 0.05$), whereas N sources, interactions of year by N sources, year by application time, N sources by application time and year by N sources by application time were not ($P > 0.05$). The result indicated that the panicle length was significantly higher and the increase in the length was 16.2% in 2009 than that of 2008 cropping year. Also significantly higher panicle length (Table 3) was obtained with the application of N in two equal splits at sowing and tillering (22.89 cm) than at tillering and panicle initiation stages (21.87 cm) that indicated the importance of N application in rice at sowing. Contrarily, Abd El-Maksoud (2008) reported that panicle length was not significantly influenced with the split application of N. Moreover, in this experiment no significant differences in panicle length were obtained between N applied in three equal splits (sowing, tillering and panicle initiation), two equal splits (sowing, panicle initiation/tillering and panicle initiation).

Number of grains:

Except experimental years ($P \leq 0.01$), the response of number of grains panicle^{-1} to N sources, application time and all the interactions were not significant ($P > 0.05$) (Table 2). The number of grains panicle^{-1} was significantly higher in 2009 and this increase was 26.5% over 2008 cropping year (Table 4). The sources of N did not bring significant influence on number of grains, but $CO(NH_2)_2$ recorded 7.2 and 7.3% more grains panicle^{-1} than NH_4NO_3 and $(NH_4)_2SO_4$ sources of N, respectively. Similarly the variation in grains panicle^{-1} was 119.2 to 136.8 due to time of N application, the highest being with the application of N ½ each at sowing and tillering and the lowest with ½ each at tillering and panicle initiation stages of the crop. The trend in number of grains panicle^{-1} was similar to panicle length, therefore this parameter might be influenced by the panicle length, but the significant difference in panicle length due to N application time (Table 3) however, failed to bring a significant change in number of grains panicle^{-1}. The panicle length obtained with the N application time in the study was compatible with Witt *et al.* (2007) findings who reported that N absorbed at sowing, tillering and panicle initiation stage in rice plant ensured a sufficient number of panicles with increased number of spikelet (flower) panicle^{-1} that develop into increased grain number panicle^{-1}.

Panicle grain weight:

The effects of experimental year ($P \leq 0.01$) and sources of N application time ($P \leq 0.05$) on panicle grain weight were significant, while the effects of sources of N and the all interactions were not found to be significant($P > 0.05$) on rice grain weight panicle^{-1} (Table 2). Like panicle length and grains panicle^{-1}, the grain weight panicle^{-1} was significantly ($P \leq 0.05$) higher in 2009 than 2008. Regardless of N sources and application time, the grain weight panicle^{-1} was 21.4% higher in 2009 than in 2008. Significantly more panicle length and grains panicle^{-1} might have contributed to significant increase in grain weight panicle^{-1} (Tables 3 and 4). The sources of N had no significant difference in grain weight panicle^{-1} but it varied from 3.11g (NH_4NO_3) to 3.37g (CO $(NH_2)_2$). Unlike this study, Chaturvedi (2005) found significantly highest (1.97g) grain weight panicle^{-1} with $(NH_4)_2SO_4$ and lowest (1.24 g) with CO $(NH_2)_2$ treatment. The highest (3.50 g) grain weight panicle^{-1} was obtained with the application of N ½ at sowing and tillering stages of rice, but it did not vary significantly with the grain weight recorded with ½ at sowing and panicle initiation (3.32g) and ⅓ at sowing, tillering and panicle initiation (3.18 g) stages.

The significantly more panicle length due to cropping year and application time (Table 3) and insignificantly higher grain number panicle^{-1} when N was applied ½ each at sowing and tillering might have resulted in a significant increase in grain weight panicle^{-1} over N application also in two equal splits but at tillering and panicle initiation stages (Table 4).

1000-grain weight:

Similar to number of effective tillers m^{-2} and leaf area index, 1000-grain weight insignificantly ($P > 0.05$)affected by experimental years, sources of N, application time and their interactions (Table 2). There was no statistical difference ($P > 0.05$) between the experimental years for 1000-grain weight of NERICA-3 rice. However, in first experimental year more 1000-grain weight (26.11 g) was recorded than in the second year (25.93 g) (Table 4). Similarly, 1000-grain weight of rice ranged from 25.86 to 26.33g and 25.7 to 26.43 g, with the sources of N and time of N application, respectively (Table 4). But, in hybrid rice Proagro 6207, Chaturvedi (2005) used calcium ammonium nitrate, urea, supper net (25.5% N and 9.8% S), ammonium sulfate nitrate and 20-10-12 NPK compound fertilizer and found increased 1000-grain weight with super net and decreased with $CO(NH_2)_2$ treatment. Availability of nutrients and better plant growth might be the reason for heavier grain with super net. Generally, grain weight is a genetically controlled trait, which is greatly influenced by environmental conditions prevailing during the process of grain filling (Kausar *et al.*, 1993).

Table 4. Effects of year, N sources and application time on number of grains panicle^{-1}, grain weight panicle^{-1}, 1000-grain weight, yield and grain protein of rice.

N sources	No. of grains panicle^{-1}	Grain weight panicle^{-1} (g)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Grain protein (%)
Year						
2008	111.1b	2.94b	26.11	4.22b	5.40b	11.46a
2009	140.5a	3.57a	25.93	5.89a	6.88a	6.82b
NH_4NO_3	122.9	3.11	25.86	5.00	6.10	9.64
$(NH_4)_2SO_4$	122.8	3.28	26.33	4.99	6.58	8.10
$CO(NH_2)_2$	131.7	3.37	25.97	5.17	5.73	9.69
Application time (AT)						
AT_1	136.8	3.50a	25.70	5.38	6.88	8.75
AT_2	123.4	3.18ab	25.82	4.98	6.05	9.67
AT_3	123.8	3.32ab	26.43	5.06	5.82	9.25
AT_4	119.2	3.00b	26.14	4.79	5.79	8.92
CV (%)	17.91	15.73	6.70	23.20	31.99	39.72

Means of the same factor in a column followed by the same letter are not significantly different at P > 0.05 by Duncan's multiple range test; AT_1 = ½ at sowing + ½ at tillering; AT_2 = ⅓ at sowing + ⅓ at tillering + ⅓ at panicle initiation; AT_3 = ½ at sowing + ½ at panicle initiation; AT_4 = ½ at tillering + ½ at panicle initiation; CV = Coefficient of variation

Table 5. Interaction effects of N sources and application time on rice grain yield (t ha^{-1}).

N Sources	Application time			
	AT_1	AT_2	AT_3	AT_4
NH_4NO_3	6.33a	4.88ab	4.34b	4.46b
$(NH_4)_2SO_4$	5.45ab	4.64b	5.43ab	4.42b
$CO(NH_2)_2$	4.36b	5.42ab	5.39ab	5.50ab

Means of the same factor in a row or a column followed by the same letter are not significantly different at P > 0.05 by Duncan's Multiple Range test. AT_1 = ½ at sowing + ½ at tillering; AT_2 = ⅓ at sowing + ⅓ at tillering + ⅓ at panicle initiation; AT_3 = ½ at sowing + ½ at panicle initiation; AT_4 = ½ at tillering + ½ at panicle initiation

Grain yield:

The analyses of variance revealed that the response of grain yield to cropping year ($P \leq 0.01$) and interaction of sources of N and application time ($P \leq 0.05$) were significant while N sources, application time, interactions of year by N sources, year by application time and year by N sources by application time were not ($P > 0.05$) (Table 2).

Regardless of N sources and time of application, significantly higher grain yield (5.89 t ha^{-1}) was obtained during 2009 and the increase in grain yield was 39.6% over 2008 cropping year. Despite lower 1000 grain weight, higher tillers m^{-2} and the significantly higher panicle length, number of grains and grain weight $panicle^{-1}$ might have contributed to increase in grain yield (Tables 3 and 4). In addition the air temperature in 2009 was comparatively more than the 2008 cropping year. According to Akita (1989) crop environmental conditions with high solar radiation and abundant supply of N favored accumulation of high amount of biomass and high yield provided varieties respond favorably to N.

The grain yield of rice due to main effects of N sources and application time ranged from 4.99 - 5.17 and 4.79 - 5.38 t ha^{-1}, respectively that was not significant ($P > 0.05$). However, Table 5 showed that significantly ($P \leq 0.05$) higher rice grain yield was obtained with NH_4NO_3 applied into equal splits (sowing and tillering) that had no significant difference with the grain yield recorded with NH_4NO_3 applied in three equal (sowing, tillering and panicle initiation stages), $(NH_4)_2SO_4$ applied ½ at sowing + ½ at tillering and ½ at sowing + ½ at panicle initiation and $CO(NH_2)_2$ applied at all times except ½ at sowing + ½ at tillering. Significantly decreased grain yield observed with NH_4NO_3 applied ½ at sowing + ½ at panicle initiation but had no significant variation with grain yield obtained with NH_4NO_3, $(NH_4)_2SO_4$ and $CO(NH_2)_2$ applied at all times except with NH_4NO_3 applied ½ at sowing + ½ at tillering.

This increased grain yield might be due to cumulative effect of more panicle length, number of grains and grain weight $panicle^{-1}$ in $CO(NH_2)_2$ than $(NH_4)_2SO_4$ and NH_4NO_3 treated plots in spite of lower number of tillers m^{-2} (Tables 3 and 4). Likewise, these parameters might have also performed better contribution to higher yield when the fertilizer applied ½ at sowing + ½ at tillering than at other time of applications. Similar results have been reported by Viraktamath (2006) who reported increase in rice grain yield due to the increased yield attributing characters like panicle number, panicle length, 1000-grain weight and low sterility percentage. The lowest grain yields (4.99 and 4.79 t ha^{-1}) were found with $(NH_4)_2SO_4$ and the N applied ½ at tillering + ½ at panicle initiation, respectively. Maragatham, *et al.* (2010) also stated that rice grain yield obtained with recommended $(NH_4)_2SO_4$ was found lower than the yield gained with recommended N as $CO(NH_2)_2$. This might be due to continuous and steady supply of N into the soil solution to meet the required nutrients for physiological processes, which in turn improved the yield. Also increased nutrient uptake especially of N and P resulted in increased photosynthetic rate and increased plant growth. Increased photosynthetic rate resulted in higher translocation to sink and more grain yield. After panicle initiation and at 100 ppm N, nitrate is better source for rice than ammonia (Reddy, 2006). Under neutral to warm soil or alkaline soil, $CO(NH_2)_2$ performed equally to NH_4NO_3 by reducing N losses through volatilization (Mahler *et al.*, 1994; Jan *et al.* 2010). However, Chaturvedi (2005) reported that sulfur containing N fertilizer had significant effect on rice grain yield of hybrid rice (Proagro 6207) than the non sulfur containing nitrogenous fertilizers.

Based on panicle length, grain number and weight $panicle^{-1}$, N fertilizer applied at or near seeding time was usually the most effective for increasing yields (Tables 4). Hence, NERICA-3 responded better to application of N ½ at sowing + ½ at tillering, ½ at sowing + ½ panicle initiation and ⅓ at sowing +⅓ at tillering + ⅓ at panicle initiation and resulted respectively, in 12.3,5.6 and 4.0% increase in yield than ½ at tillering + ½ panicle initiation (Table 4.). Therefore, avoiding N fertilizer application at sowing may prove detrimental to the crop yield. Therefore, split application of N is imperative to increase the N use efficiency of rice; to reduce loss of N fertilizer and environmental pollution. However, Sallam (2005) and Abd El-Maksoud (2008) found splitting N to four doses, provided the rice plants with N throughout the vegetative growth period. This may explain the favorable effect of splitting N fertilizer on yield attributing traits. These effects led the grain yield and aboveground biomass to be affected positively by splitting the N fertilizer to 3 or 4 doses.

Straw yield”

The rice straw yield showed significant ($P \leq 0.05$) respond to experimental years and the interaction of N sources by application time whereas its response to N sources, application time, interactions of year by N sources, years by application time and years by N sources by application time were not (Table 2). Like grain yield, the straw yield was significantly ($P \leq 0.05$) higher in 2009 than 2008 cropping year. In the 2009 the straw yield (6.88 t ha^{-1}) was 27.4% higher than in 2008 cropping year. Higher leaf area index, number of tillers m^{-2} and significantly more panicle length in 2009 than 2008 cropping year (Table 3.) might have contributed to increase in straw yield. On the other hand the interaction data (Table 6.) indicated that the application of $(NH_4)_2SO_4$ applied ½ at sowing + ½ at tillering resulted in the highest straw yield (8.64 t ha^{-1}) that did not vary significantly with the interaction of NH_4NO_3 applied ½ at sowing + ½ at tillering and ⅓ at sowing + ⅓ at tillering + ⅓ at panicle initiation, $(NH_4)_2SO_4$ ½ at sowing + ½ at panicle initiation and $CO(NH_2)_2$ ½ at sowing + ½ at panicle initiation and ½ at tillering + ½ at panicle initiation stages (Table 6). Whereas, Manzoor *et al.* (2006) indicated that among four N application times used on fine rice, three equal splits showed maximum straw yield. The magnitude of increase in rice straw yield with $(NH_4)_2SO_4$ ½ at sowing + ½ at tillering was 90.73% over the lowest straw yield (4.53 t ha^{-1}) recorded with NH_4NO_3 applied ½ at sowing + ½ at panicle initiation (Table 6). Better straw yield could be explained as higher capability of hybrid rice to utilize more N through the expression of better growth by accumulating more dry matter.

Maragatham, *et al.* (2010), however, found lowest straw yields of Indica and Japonica rice from recommended $(NH_4)_2SO_4$ treatment. They added, the plants grown on plots supplied with $(NH_4)_2SO_4$ exhibited wilting followed by development of tip-burns in the lower leaves which subsequently spread over the whole blade. Their roots were darkened, poorly branched and appeared much less healthy than those of NH_4NO_3, or $(NH_4)_2SO_4$ + NH_4NO_3 fed plants.

Grain protein content:

The grain protein content was significantly ($P \leq 0.01$) affected by the experimental year, while insignificant difference occurred due to N sources, sources of N application time and the interactions (Table 2).

Grain protein contents were 11.46 and 6.82% in 2008 and 2009, respectively (Table 4). However, the highest grain protein content (9.69 and 9.67%) was recorded with $CO(NH_2)_2$ and the application of N in three equal splits (at sowing, tillering and panicle initiation stages), respectively. $CO(NH_2)_2$ is effective in most crops and can be applied to all soils as the acidity will not increase with regular use of $CO(NH_2)_2$ compared to $(NH_4)_2SO_4$. (Freney *et al.*, 2009). The lowest protein content was obtained with $(NH_4)_2SO_4$ (8.10%) and application of N ½ at sowing + ½ at tillering (8.75%). TNAU (2008) study reveal that $(NH_4)_2SO_4$ fertilizer is not effective in acid soils since the ammonium ions are readily absorbed on the colloidal complex of the soil, but it is effective in saline and alkali soils. The higher protein content of N treated plants could be related with the positive effect of N on some important physiological processes (Chaturvedi, 2005). Similar to this study, Abd El-Maksoud (2008) reported that rice grain quality was not affected by split application of N fertilizer.

Table 6. Interaction effects of N sources and application time on rice straw yield (t ha^{-1})

N Sources	Application time			
	AT_1	AT_2	AT_3	AT_4
NH_4NO_3	7.25ab	6.96ab	4.53b	5.67b
$(NH_4)_2SO_4$	8.64a	5.44b	6.81ab	5.44b
$CO(NH_2)_2$	4.76b	5.76b	6.12ab	6.27ab

Means of the same factor in a row or a column followed by the same letter are not significantly different at P > 0.05 by Duncan's Multiple Range test. AT_1 = ½ at sowing + ½ at tillering; AT_2 = ⅓ at sowing + ⅓ at tillering + ⅓ at panicle initiation; AT_3 = ½ at sowing + ½ at panicle initiation; AT_4 = ½ at tillering + ½ at panicle initiation

Table 7. Partial budget with dominance to estimate net benefit for application of $CO(NH_2)_2$, NH_4NO_3 and $(NH_4)_2SO_4$ fertilizers at current prices.

Treatment	Partial budget with dominance				
	Total grain yield (t ha^{-1})	Adjusted yield (t ha^{-1})	GFB (ETB ha^{-1})	TCV (ETB ha^{-1})	NB (ETB ha^{-1})
$CO(NH_2)_2/AT_1$	4.36	3.05	12208	4370.65	7837.35U
$CO(NH_2)_2/AT_3$	5.39	3.77	15092	5183.45	9908.55U
$CO(NH_2)_2/AT_2$	5.42	3.79	15176	5232.53	9943.47U
$CO(NH_2)_2/AT_4$	5.50	3.85	15400	5273.77	10126.23U
NH_4NO_3/AT_3	4.34	3.04	12152	5406.77	6745.23D
NH_4NO_3/AT_4	4.46	3.12	12488	5497.09	6990.91D
NH_4NO_3/AT_2	4.88	3.42	13664	5862.26	7801.74D
$(NH_4)_2SO_4/AT_4$	4.42	3.09	12376	6912.37	5463.63D
NH_4NO_3/AT_1	6.33	4.43	17724	6975.94	10748.06U
$(NH_4)_2SO_4/AT_2$	4.64	3.25	12992	7119.49	5872.51D
$(NH_4)_2SO_4/AT_3$	5.43	3.80	15204	7713.89	7490.11D
$(NH_4)_2SO_4/AT_1$	5.45	3.82	15260	7736.46	7523.54D

Field price of $CO(NH_2)_2$ = Birr 3.38 per kg; Field price of NH_4NO_3 = Birr 6.38 per kg; Field price of $(NH_4)_2SO_4$ = Birr 5.88; Wage rate = Birr 25 per day; Labor to apply fertilizer per ha = 2 and 3 man-day for 2 and 3 split application times, respectively; Retail price of grain = Birr 4000 per ton; HTW= Harvesting, threshing and winnowing cost = Birr 1000 per ton; BMT = Bagging, material and transport cost = Birr 65 per ton ; GFB = Gross field benefit; TCV = Total cost that varied; NB = Net benefit; AT_1 = ½ at sowing + ½ at tillering; AT_2 = ⅓ at sowing + ⅓ at tillering + ⅓ at panicle initiation; AT_3 = ½ at sowing + ½ at panicle initiation; AT_4 = ½ at tillering + ½ at panicle initiation; U = Undominated; D = Dominated

Grain protein contents were 11.46 and 6.82% in 2008 and 2009, respectively (Table 4). However, the highest grain protein content (9.69 and 9.67%) was recorded with CO $(NH_2)_2$ and the application of N in three equal splits (at sowing, tillering and panicle initiation stages), respectively. CO $(NH_2)_2$ is effective in most crops and can be applied to all soils as the acidity will not increase with regular use of CO $(NH_2)_2$ compared to $(NH_4)_2SO_4$. (Freney *et al.*, 2009). The lowest protein content was obtained with $(NH_4)_2SO_4$ (8.10%) and application of N ½ at sowing + ½ at tillering (8.75%). TNAU (2008) study reveal that $(NH_4)_2SO_4$ fertilizer is not effective in acid soils since the ammonium ions are readily absorbed on the colloidal complex of the soil, but it is effective in saline and alkali soils. The higher protein content of N treated plants could be related with the positive effect of N on some important physiological processes (Chaturvedi, 2005). Similar to this study, Abd El-Maksoud (2008) reported that rice grain quality was not affected by split application of N fertilizer.

Table 8. Partial budget with estimated marginal rate of return (%) N sources

Treatment	Marginal rate of return (MRR%)				
	TCV (ETB ha^{-1})	NB (ETB ha^{-1})	Raised cost	Raised benefit	MRR%
$CO(NH_2)_2/AT_1$	4370.65	7837.35			
$CO(NH_2)_2/AT_3$	5183.45	9908.55	812.80	2071.20	254.82
$CO(NH_2)_2/AT_2$	5232.53	9943.47	49.08	34.92	71.15
$CO(NH_2)_2/AT_4$	5273.77	10126.23	41.24	182.76	443.16
NH_4NO_3/AT_1	6975.94	10748.06	1702.17	612.83	36.00

ETB = Ethiopian Birr; TCV = Total cost that vary; NB = Net benefit; AT_1 = ½ at sowing + ½ at tillering; AT_2 = ⅓ at sowing + ⅓ at tillering + ⅓ at panicle initiation; AT_3 = ½ at sowing + ½ at panicle initiation;AT_4 = ½ at tillering + ½ at panicle initiation

Table 9. Sensitivity analysis of rice production after different practices based on a 15% rise in total cost and rice price of gross field benefit fall

Treatment	TCV (ETB ha^{-1})	NB (ETB ha^{-1})	Increment cost	Increment benefit	MRR%
$CO(NH_2)_2/AT_1$	5026.25	6661.75			
$CO(NH_2)_2/AT_3$	5960.97	8422.27	934.72	1760.52	188.35
$CO(NH_2)_2/AT_4$	6064.84	8607.30	103.87	185.03	178.14

ETB = Ethiopian Birr; TCV = Total cost that vary; NB = Net benefit; MRR=Marginal rate of return; AT_1 = ½ at sowing + ½ at tillering; AT_3 = ½ at sowing + ½ at panicle initiation;AT_4 = ½ at tillering + ½ at panicle initiation

Economic viability of N sources and their split application on rice

Analysis of variance (Table 2) showed that sources of N fertilizer and application time had no significant (P > 0.05) effect on grain yield, but cropping year and interaction of sources of N and application time had significant effect. An economic analysis on the combined result using the partial budget technique is appropriate (CIMMYT 1988). The results of the partial budget and the economic data used in the development of the partial budget are given in Table 7.

Dominance analysis (Table 7) led to the selection of treatments CO $(NH_2)_2$ applied at all application times and NH_4NO_3 applied ½ at sowing + ½ at tillering and which ranked in increasing order of total costs that varied. Marginal rate of return below 100% was considered low and unacceptable to farmers (CIMMYT, 1988). Thus, $CO(NH_2)_2$ applied ⅓ each at sowing, tillering and panicle initiation and NH_4NO_3 applied ½ at sowing + ½ at tillering were rejected while $CO(NH_2)_2$ applied ½ each at sowing and tillering, sowing and panicle initiation, and tillering and panicle initiation were accepted (Table 8).

Therefore, this investigation remained with changes to CO $(NH_2)_2$ applied ½ at sowing + ½ at panicle initiation and ½ at tillering + ½ at panicle initiation as they gave more than 100% MRR as promising new practices for farmers under the prevailing price structure. This might suggest the use of inputs that results in maximum net benefits (Bekele, 2000). An assumption of price change of Birr 0.51 per kg of $CO(NH_2)_2$ and Birr 0.6 per kg of rice is borne out of our own experiences and represents a price fluctuation of 15%. These price changes are realistic under the liberal market conditions prevailing in Gambella among lowland dwellers at the time.

Some of the considerations in projecting prices were; increased rice supply due to aid for refugees, imports from abroad; and a deteriorating business environment in Gambella. The new prices were used to obtain the sensitivity analysis. As observed $CO(NH_2)_2$ applied ½ at sowing + ½ at panicle initiation (254.82%) and ½ at tillering + ½ at panicle initiation (443.16%) were accepted from the MRR calculation (Table 9) for giving a higher MRR than that of the minimum acceptance threshold.

From the range of treatments tested CO $(NH_2)_2$ applied ½ at sowing + ½ at panicle initiation (188.35%) and ½ at tillering + ½ at panicle inititiation (178.14%) give an economic yield response and also sustained acceptable returns even under a projected worsening trade conditions in Gambella (Table 9). It was observed that $CO(NH_2)_2$ was relatively cheaper and easy to transport than NH_4NO_3 and $(NH_4)_2SO_4$ (Obreza *et al.*, 2010). These results agree with Saha *et al.*, (1994) whose findings from coastal Kenya on maize showed that the application of 30 kg N ha^{-1} consistently gave acceptable economic returns.

On a tentative basis farmers could thus choose any of the two new application time of CO $(NH_2)_2$. As the data generated from this experiment based on small area, the results can be used to make tentative recommendations, which could be refined through multi-location testing over a wider area.

Conclusions

Results carried out for two years in a typical clay soil comparing three N sources and their split application time indicated that application of N fertilizers ½ at sowing + ½ at panicle initiation; and ½ at tillering + ½ at panicle initiation stages were effective in rice production partially due to reduce N losses.

Slow-release fertilizers, $(NH_4)_2SO_4$ and NH_4NO_3, were form less effective in rice production under acid clay soil than CO $(NH_2)_2$ because of its high N analysis, ease of handling, and lower cost. Little is known of this behavior due, with all probability, to the lack of synchronism with the peaks of plant N demand. Hence, farmers must be conscious of the different properties and behavior of these fertilizers, and should be ready to change some management practices, if necessary, to sustain high fertilization efficiency.

Therefore, in wet season and medium fertility soils, application of 92 kg N ha^{-1} as $CO(NH_2)_2$ at one of application time indicated above was found to be economical for NERICA-3 rice and efficient N utilization in agro climatic conditions of the study area. Split application of fertilizer N is likely to be the most promising strategy to increase N use efficiency, and optimizing synchrony between crop demand and supply going to remain an essential practice in rice. However, it needs further investigation in subsequent studies, involving a greater number of N sources and splits and rice varieties to formulate a general recommendation.

Acknowledgement

We would like to thank Professor Belay Kassa, the Haramaya University's President for his special help in solving the residential and laboratory service expenses of the first author.

References

Abd El-Maksoud M. F. 2008. Effect of Levels and Splitting of N-fertilization on Growth, Yield Components, Yield and Grain Quality of Some Rice Cultivars. Res. J. Agric. and Biol. Sci. **4(5),** 392-398.

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

Assefa M, Getnet F, Menzir, A, Kurabachew H. 2009. Response of upland rice for nitrogen and phosphorus fertilizers on Vertisols of Pawe area. In: Proceeding of the 10th Conference of the Ethiopian Soc. Soil Sci. held during 25-27 March 2009, Addis Ababa, Ethiopia.

Astewel T. 2010. Analysis of Rice profitability and marketing chain: The case of Fogera woreda, South Gondar Zone, Amhara National Regional State, Ethiopia. MSc Thesis, Haramaya University, Haramaya, Ethiopia.

Biloni M, Bocchi S. 2003. Nitrogen application in dry seeded delayed flooded rice in Italy. Effect on yield and crop parameters. Nutr. Cycling in Agroec. **67(2),** 117-128.

Chaturvedi I. 2005. Effect of nitrogen fertilizers on growth, yield and quality of hybrid rice (*Oryza sativa*)**.** J. Centl. Eur. Agric. **6(4),** 611-618.

CIMMYT. 1988. From agronomic data to farmer recommendations: Answers to Workbook Exercises. Mexico, DF.

FARA (The Forum for Agricultural Research in Africa). 2009. Patterns of change in rice production in Africa: Implication for rice policy development /Ministerial_Policy_brief_series _No_2.

Freney JR, Peoples MB, Mosier AR. 2009. Efficient use of fertilizer FFTC Publication, Taipei 10616 Taiwan R.O.C.

Haque KMS, Khaliq QA, Aktar J. 2006. Effect of nitrogen on phenology*,* light interception and growth in Aromatic Rice. Intl. J. Sustain. Crop Prod. **1(2),** 1-6.

Iqbal MM, Akhter J, Mohammad W, Shah SM, Nawaz H, Mahmood K. 2005. Effect of tillage and fertilizer levels on wheat yield, nitrogen uptake and their correlation with carbon isotope discrimination under rainfed conditions in north-west Pakistan. Soil and Tillage Res. **80,** 47-57.

Jan MT, Khan MJ, Khan A, Arif M, Shafi M, Farmanullah. 2010. Wheat nitrogen indices response to nitrogen source and application time. Pak. J. Bot. **42(6),** 4267-4279.

Jensen T. 2006. Nitrogen fertilizer, forms and methods of application. Proceeding of the 2006 Alberta Irrigated Crop Production Update Conference, Alberta Agriculture, Food and Rural Development, Southern Applied Research Association, 17 January, 2006, Lethbridge. p. 21-26.

Kabuye FM, Drew C. 2000. Upland rice growing manual. Africa 2000 Network and USAID-Agricultural Productivity Enhancement Program, Uganda.

Kausar K, Akbar M, Rasul E, Ahmad AN. 1993. Physiological responses of nitrogen, phosphorus and potassium on growth and yield of wheat. Pak. J. Agric. Res. **14,** 2–3

Kenzo W. 2004. Utilization advantages of controlled release nitrogen fertilizer on paddy rice cultivation. JARQ. **38(1),** 15-20.

Kichey T, Hirel B, Heumez E, Dubois F, Le-Gouis J. 2007. In winter wheat, post-anthesis nitrogen uptake and remobilization to the grain correlates with agronomic traits and nitrogen physiological markers. Field Crops Res. **102,** 22-32.

Kiran U, Patra DD. 2002. Augmenting yield and urea-nitrogen utilization efficiency in wheat through use of natural essential oils and dicyandiamide coated urea in light–textured soils of Central Uttar Pradesh. Commun. Soil Sci.Plant Anal. **33,** 1375-1388.

Krishnan P, Nayak SK. 2000. Biomass partitioning and yield components of individual tillers of rice (*Oryza sativa*) at different nitrogen levels. Indian J. Agric. Sci. **70(3),** 143-145.

Kushwaha HS, Mishra MK, Tomar RAS. 1992. Response of rice to N, P, K and Zn on Farmer's Field. Agric. Soc. Digest(Karanal) **21,** 4-6.

Limon-Ortega A, Sayre KD, Francis CA. 2000. Wheat nitrogen use efficiency in a bed planting system in northwest Mexico. Agron. J. **92,** 303-308.

Madan HS, Munjal R. 2009. Effect of split doses of nitrogen and seed rate on protein content, protein fractions and yield of wheat. ARPN J. Agric. Biol. Sci. **4(1),** 26-31.

Mahler RL, Koehler FE, Lutcher LK. 1994. Nitrogen source, timing of application, and placement: Effects on winter wheat production. Agron. J. **86,** 637-642.

Mandal NN, Chaudhry PP, Sinha D. 1992. Nitrogen, phosphorus and potash uptake of wheat (var. Sonalika). Env. Eco. 10, 297 (Field Crop Abst. **46(1),** 30.

Manzoor Z, Ali RI, Awan TH, Khalid N, Ahmad M. 2006. Appropriate time of nitrogen application to fine rice, *Oryza sativa***.** J. Agric. Res. **44(4),** 261-266.

Maragatham M, Martin GJ, Poongodi T. 2010. Effect of Nitrogen sources on aerobic rice production under various rice soil ecosystems. 19th World Congress of Soil Sci. Soil Solutions for a Changing World, 1- 6 August 2010, Brisbane, Australia.

Marschner H. 1995. Mineral nutrition of higher plants. 2nd Edition. Academic Press. San Diego, CA.

Mengel K, Kirkby EA. 1996. Principles of Plant Nutrition. Panina Publishing Corporation, 4th edn, New Delhi.

MoARD (Ministry of Agriculture and Rural Development). 2010. National Rice Research and Development Strategy of Ethiopia. Addis Ababa, Ethiopia.

Mossedaq F, Smith DH. 1994. Timing nitrogen application to enhance spring wheat yields in Mediterranean climates. Agron. J. **86,** 221-226.

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

Obreza T, Parsons L, Morgan K. 2010. Nitrogen fertilizer sources: What does the future hold for citrus producers. IFAS Extension, University of Florida.

Padmavathi P. 1997. Studies on relative performance of conventional and hybrid rice varieties under various levels of nitrogen, plant population and planting paterns. PhD thesis, Indian Agricultural Research Institute, New Delhi.

Pan J, Zhu Y, Jiang D, Dai T, Li Y, Cao W. 2006. Modeling plant nitrogen uptake and grain nitrogen accumulation in wheat. Field Crops Res. **97**, 322-336.

Raza M, Khan H, Karim F, Tahir MJ. 2003. Nitrogen use efficiency as affected by time of application in rice (IRRI-6). Sarhad J. Agric. **19(4),** 453- 457.

Reddy SR. 2006. Agronomy of field crops. Kalyani Publishers, New Delhi, India. 65-68.

Roy P, Orikasa T, Okadome H, Nakamura N, Shiina T. 2011. Processing conditions, rice properties, health and environment. Intl. J. Environ. Res. Public Health **8,** 1957-1976.

Rupp D, Hubner H. 1995. Influence of Nitrogen fertilization on the mineral content of apple leaves. Erwerbsobstbau, **37,** 29-31.

Salem AKM. 2006. Effect of nitrogen levels, plant spacing and time of farm yard manure application on the productivity of rice. J. Appl. sci. Res. **2(11),** 980-987.

Sallam STM. 2005. Studies on yield potentiality of Giza 177 and Sakha 101 rice cultivars under the effect of biofertilization and splitting of nitrogen. PhD. Thesis Fac. Agric. Zagazig Univ., Egypt.

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

Sathiya K, Ramesh T. 2009. Effect of split application of nitrogen on growth and yield of aerobic Rice. Asian J. Exp. Sci. **23 (1),** 303-306.

Shah H, Sharif M, Majid A, Hayat U, Munawar A. 2009**.** From experimental data to farmer recommendation: an economic analysis of on-farm trial of UMMB feed for milking animals in rain-fed Pothwar, Pakistan. Livestock Research for Rural Development, 21(117).

TNAU (**Tamil Nadu Agricultural University**). 2008. Nutrient management: Fertilizers, Coimbatore, India.

Tran TS, Tremblay G. 2000. Recovery of N-15-labeled fertilizer by spring bread wheat at different N rates and application times. Can. J. Soil Sci. 80, 533-539.

Tsunoda S.1964. A developmental analysis of yielding ability in varieties of field crops. Nihon Gakujitsu Shinkokai, Tokyo, Japan.

Viraktamath BC. 2006. Evaluation of system of rice Intensification (SRI) under all India coordinated rice improvement project. In: Abstracts of National Symposium on System of Rice Intensification (SRI)–Present status and future prospects, November 17-18, India.

Witt C, Buresh RJ, Peng S, Balasubramanian V, Dobermann A. 2007. Nutrient management. p 1-45. In: T. H. Fairhurst, C. Witt, R. Buresh and A. Dobermann, eds. Rice: A practical guide to nutrient management. Los Baños (Philippines) and Singapore: International Rice Research Institute (IRRI), International Plant Nutrition Institute (IPNI), and International Potash Institute (IPI).

Wuest SB, Cassman KG. 1992. Fertilizer-nitrogen use efficiency of irrigated wheat: Uptake efficiency of preplant versus late-season application. Agron. J. **84,** 682-688.