Influence of Time of Nitrogen Application on Productivity and Nitrogen Use Efficiency of Rain- fed Lowland Rice *(Oryza sativa L.)* in the Vertisols of Fogera plain, Northwestern Ethiopia

Alemayehu Assefa[1], Tilahun Tadese[1*], and Minale Liben[1]
[1]*Agronomists, Adet Agricultural Reserch Center, PO Box 8, Bahir Dar, Ethiopia*
[*]*Corresponding author: tilahuntade@yahoo.com*

Abstract

An experiment consisting of two fertilizer rates (69/10 and 46/20 kg N/P ha^{-1}) and five nitrogen (N) application times (half at planting + half at tillering (control), half at planting + half at panicle initiation, one-third at planting + two-third at tillering, one-third at planting + two-third at panicle initiation and one-third at planting + one-third at tillering +one-third at panicle initiation) was conducted in factorial RCBD on the Vertisols of Fogera plain during the 2006 and 2007 cropping seasons. The objective of the experiment was to identify the best time of N application for maximum rain-fed lowland rice yield in the Fogera plain. Results showed significant difference in grain yield in response to the time of N application. The highest mean grain yield (4409 kg ha^{-1}) was recorded when N was applied one-third at planting and two-third at the tillering stage of the crop. Nitrogen fertilizer rates and the interaction with its time of application showed non-significant differences for all parameters. The agronomic Nitrogen Use Efficiency (NUE) was found to be higher for one-third at planting and two-third at tillering nitrogen application compared to the other treatments. Hence, application of nitrogen one-third at planting and two-third at tillering stage of rice, irrespective of the fertilizer rate, is recommended for rice production in the Fogera plain.

Keywords: split application, yield, NUE,.

1. Introduction

Rice (*Oryza sativa* L.) is an important food crop of the world. In Ethiopia, rice has become one of the most important crops whereby its production and area coverage increase every year, especially in the Fogera plain (Tesfaye *et al.*, 2005). Agronomic management factors play an important role in rice production. For instance, fertilizer rate recommendations of 69/23 and 46/46 kg N/P_2O_5 ha^{-1} increased rice grain yield by 43% and 38% respectively over the unfertilized treatment in the Fogera plain (Tilahun *et al.*, 2007). There is a wide difference between Ethiopia (3 t ha^{-1}) and other countries such as China (6.05 t ha^{-1}); Japan (6.21 t ha^{-1}) and South Korea (6.99 t ha^{-1}) in terms of average yield (Aamer *et al.*, 2000; Tesfaye, *et al.*, 2005). An inadequate fertilizer applied through improper application technique is one of the factors responsible for low yield of rice (Aamer *et al.*, 2000). Availability of plant nutrients, particularly nitrogen at various plant growth stages is of crucial importance in rice production. Increasing the fertilizer use efficiency is very important, particularly in developing countries where the cost of fertilizer is rather very high and increasing. The judicious use of fertilizers contributes a lot towards improving the yield and quality of grain (Aamer *et al.*, 2000).

Most crop plants recover only 25-35% of the nitrogen applied as fertilizers (Kissan-Kerala, 2007). Losses occur by volatilization, denitrification, and immobilization to organic forms, leaching and run off. Measures to reduce the loss of N from applied urea include use of slow N releasing fertilizers like urea super granules or urea briquettes or sulphur or lac coated urea (Kissan-Kerala, 2007). Utmost care should be bestowed in selecting the type of fertilizer as well as the timing and method of application. Increasing the congruence between crop N demand and N supply improves N use efficiency in lowland rice (Cassman *et al.*, 1998).

Slow-releasing N fertilizers of silica-polymer-coated urea and sulfur-coated urea improve the availability of the nutrient to the crop and increase the rice yield (Aragon *et al.*, 1984). However, the slow-releasing N fertilizers are mostly expensive and unavailable. Linquist and Sengxua (2003) reported that deep placement of Urea Super Granules (USG) has not been adopted by farmers because it is very laborious. Taking into account the unavailability and cost of controlled release fertilizers, multiple applications of urea remain a better option than use of controlled release fertilizers for farmers in rain-fed lowland areas (Castillo, 2006). Split application of nitrogen fertilizer was found to increase rice yield whereby two to three equal splits at different growth stages resulted in significant increase in yield and yield components over single dose (Zaheen *et al.*, 2006). .

Recommendations on different period of nitrogen fertilizer application were given for various production systems. Dobermann and Fairhurst (2000) indicated that the number of splits is affected by the total amount of nitrogen fertilizer to be applied based on the desired yield level. According to James and Stribbling (1995), the optimum time of nitrogen fertilizer application could be affected by several factors like rice variety, total amount of nitrogen to be applied, soil type, climate and crop rotation. For the Fogera plain, fertilizer recommendations were given for rice production. However, the number of splits and time of application were not yet studied. Thus, this study was conducted to find out the best time of nitrogen fertilizer application for maximum rice productivity.

2. Materials and Methods

Description of the site

The experiment was conducted during the 2006 and 2007 cropping seasons on the Vertisols of Fogera plain. Fogera plain belongs to the moist tepid to cool agro-ecological zone and to the tepid to cool moist plains sub agro-ecology (CEDEP, 1999). It is located in the South Gondar Administrative Zone, north western Ethiopia, located at 13^0 19’ latitude, 37^0 03’ longitude and altitude of 1815 meters above sea level. The nine years’ (1998-2004, 2006 & 2007) mean annual rainfall in the area, as to Woreta metrology station, is 1317 mm. Based on the available temperature data at Addis Zemen metrology station, which is at the vicinity of the experimentation area, the four years’ (2004-2007) mean monthly maximum and minimum temperature is 29.8^{O}C and 9.4^{O}C, respectively. The experimental soil was clayey in texture with a pH of 5.8.

Experimental Design and Procedure

The experiment was laid in a factorial randomized complete block design with three replications. Two economically feasible fertilizer rates (69/10 and 46/20 kg N/P ha^{-1}) recommended for the area (Tilahun *et al.*, 2007) were combined with five nitrogen fertilizer application times (half at planting + half at tillering (control), half at planting + half at panicle initiation, one-third at planting + two-third at tillering, one-third at planting + two-third at panicle initiation and one-third at planting + one-third at tillering + one-third at panicle initiation). Applications at tillering and panicle initiation stages were done at about 50 and 105 days after planting, respectively. All doses of phosphorus fertilizer were applied at planting. The gross and net plot sizes were 4 m x 3 m and 3 m x 2 m, respectively. Variety *X-Jigna* was used as test crop and broadcasted at the rate of 100 kg ha^{-1}. Data on grain yield, fertile panicle number, thousand grain weight, and plant height were collected from the net plot. The data were subjected to analysis using Statistical Analysis System (SAS) Version 9.2 (SAS Inc., 2002). Agronomic Nitrogen Use Efficiency (NUE) was calculated as extra kilogram of grain per extra kilogram of N applied (Mushayi *et al.*, 1999; Hatfield and Prueger, 2004).

3. Results

The analysis of variance for individual sites indicated significant grain yield differences in response to time of nitrogen application in two of the four sites (Table 1). However, the interaction effects of nitrogen fertilizer rates and time of application were not significant in all sites. In all of the sites, the application of nitrogen (one-third at planting and two-third at tillering) gave the highest yield, with a yield advantage ranging from 1 to 24% over the control.

The combined analysis over sites and years revealed significant difference in grain yield in response to time of nitrogen application (Table 2). The highest mean grain yield of 4409 kg ha^{-1} was obtained when nitrogen was applied one-third at planting and two-third at tillering. The lowest yields of 3767 and 3772 kg ha^{-1} were obtained when nitrogen was applied half at planting plus half at panicle initiation, and one-third at planting plus one-third at tilleting plus one-third at panicle initiation respectively (Table 3). The yields of the two treatments were significantly different from the application of N 1/3 at planting and 2/3 at tillering. Nitrogen rate and its interaction with time of N application did not show any significant difference for all the parameters. Site interaction with any of the factors (N rate and/or time of N application) showed non significant difference for grain yield indicating the similarity of the sites and the possibility of applying the same package in Fogera plain irrespective of sites. Though the interaction effect of N rate by time of its application was insignificant, the highest yields for both N rates (69 and 46 kg N ha^{-1}) were achieved when split was applied one-third at planting and two-third at tillering stage of the crop. This indicates that relatively the highest amount of nitrogen should be applied at tillering as compared to planting time and panicle initiation so as to promote the maximum number of grains and subsequently higher grain yield. The highest NUE was observed when nitrogen was applied one-third at planting and two-third at tillering stage of the crop (Table 4). The specified N application gave an average of 80% NUE which was 8% superior over the control, split application of half at planting and the other half at tillering.

4. Discussion

The results indicated that the highest yields for both 69 and 46 kg N ha^{-1} were achieved when N was split applied, one-third at planting and two-third at tillering stage of the crop. The finding is in harmony with previous recommendations on split applications of N fertilizer for rice production (George, 1980; Marqueses *et al.*, 1988; Haefele *et al.*, 2006). Though a number of authors recommended two split applications, there are variations in the timings of nitrogen application for rice. Marqueses *et al.* (1988) reported that band application of 1/3 N at 20 days after seeding + 2/3 N at 5-7 days before panicle initiation gave significantly higher grain yield (8.5 t/ha) and agronomic efficiency. George (1980) indicated two splits application given at maximum tillering and panicle initiation stages was found to be better in grain yield. For the rain-fed lowland rice production of Thailand, Haefele *et al.* (2006) recommended nitrogen application in two splits as basal and top dressed at panicle initiation. Charles (2003) also recommended two splits application of nitrogen for rice where the first split is applied at planting and the remaining at internodes elongation. According to Aamer *et al.* (2000), half of the nitrogen should be applied at planting and the remaining half at the tillering stage of the crop.

On the other hand, Stevens *et al.* (2001) recommended three times application of nitrogen; at basal, at early-maximum tillering and panicle initiation. Zaheen *et al.* (2006) indicated that the treatment with N applied in three equal splits (1/3 N at planting + 1/3 N at 50 % tillering + 1/3 N at panicle initiation) showed maximum paddy yield over once and twice split N applications. Similarly, a number of findings showed that application of N in three equal splits at planting, active tillering and panicle initiation increased yields compared to a single application at planting (De Datta *et al.*, 1988; Ohnishi *et al.,* 1999, Linquist and Sengxua, 2003; FAO, 2005). There are also some reports recommending four splits of nitrogen applications. Sathiya and Ramesh (2009) recommended nitrogen application in four splits – 1/6 at 15 days after sowing, 1/3 at tillering, 1/3 at panicle initiation, 1/6 at flowering- is suitable nitrogen management technique for rice. Furthermore, Consuelo *et al*. (1996) stated that nitrogen fertilizer needs to be applied in four splits; at basal, maximum tillering, panicle initiation and flowering.

The results of the current experiment revealed the advantage of applying one-third of the recommended N at planting and two-third at tillering stage of the crop. In line with this finding, Cassman *et al.* (1998) claimed that a greater portion of the N requirement should be applied during active tillering, when crop growth is rapid and N demand is high. The N demand at the very young growth stage of the rice crop is so low (Schnier *et al.* 1987). Furthermore, N availability from the mineralization of organic matter is high during the early growing stage (Dei and Yamasaki, 1979) and should be adequate to meet crop needs.

Low Nitrogen Use Efficiency (NUE) continues to be a problem in wetland rice situation as nitrogen (N) is subjected to several transformation losses in the rice ecosystem (Hussain *et al*., 2009). The optimum use of N can be achieved by matching supply with crop demand (Hussain *et al.,* 2009). The agronomic Nitrogen Use Efficiency (NUE), which was expressed as grain production per unit of N applied, showed higher value when nitrogen was applied one-third at planting and two-third at tillering stage of the rice crop as compared to the other treatments.

The specified treatment gave 95 and 65% NUE for the rates of 46 N and 69 kg/ha N respectively. Compared to the control treatment, where one-half was applied at planting and the other half at tillering, application of one-third N at planting and two-third at tillering gave 49% and 8% NUE advantage at the 46 and 69 kg/ha N, respectively. Similar to this finding, James and Stribbling, (1995) reported that split application of nitrogen increased nitrogen uptake and use efficiency of the rice crop. They further elaborated the increase in grain yield with increasing number of N splits might be due to a reduction in nitrogen loss by volatilization and leaching, which in turn resulted in efficient nitrogen uptake by rice plants and finally resulted in better growth development and yield.

Table 1. Analysis of variance for the grain yield of rice for individual sites in the Vertisols of Fogera plain

Source of variation	Site-1	Site-2	Site-3	Site-4
N rate (N)	NS	NS	NS	NS
Time of N application (T)	*	*	NS	NS
N X T	NS	NS	NS	NS
Mean yield (kg ha^{-1}) of control (T1)	4309	3872	2912	4796
Highest mean yield (kg ha^{-1})	5353	4142	2940	5203
Time of N application for highest mean yield	T3	T3	T3	T3
Yield advantage over the control (%)	24.2	7.0	1.0	8.5
SE	153.65	108.17	112.21	152.08

* Significant at 5 % level of significance, NS Non-significant
T1 = N applied half at planting + half at tillering (control)
T3 = N applied one-third at planting + two-third at tillering

Table 2. Combined analysis of variance for the grain yield and other yield components of rice in the Vertisols of Fogera plain, 2006 and 2007

Source of variation	Grain yield (kg/ha)	Number of fertile panicles /m^2	Thousand grain weight (g)	Plant height (cm)
Site(S)	**	NS	**	**
N	NS	NS	NS	NS
SxN	NS	NS	*	NS
Time of N application (T)	*	NS	NS	NS
SxT	NS	NS	NS	NS
NxT	NS	NS	NS	NS
SxN x T	NS	NS	NS	NS
SE	101.44	5.19	0.23	0.78

*, ** Significant at 5 & 1% level of significance respectively, NS= Non-significant

Table 3. Effect of nitrogen fertilizer rate and nitrogen application time on the grain yield of rice in the Vertisols of Fogera plain, combined over sites

	Fertilizer rates (kg/ha)		
Time of N application	46/20N/P	69/10 N/P	Mean
Half at planting and half at tillering (control)	4001	3944	3972[b]
Half at planting and half at panicle initiation	3899	3635	3767[b]
One-third at planting and two-third at tillering	4357	4462	4409[a]
One-third at planting and two-third at panicle initiation	3961	4215	4088[ab]
One-third at planting, one-third at tillering and one-third at panicle initiation	4120	3425	3772[b]
Mean	4067	3936	
SE	101.44		

Numbers followed by different letters on the same column indicate significant differences at 5% level of significance using Duncan's multiple range test.

Table 4. Effect of nitrogen fertilizer split applications on Nutrient Use Efficiency (NUE) of rice

Time of N application	NUE at 46 kg N	NUE at 69 kg N
Half at planting and half at tillering (control)	87	57
Half at planting and half at panicle initiation	85	53
One-third at planting and two-third at tillering	95	65
One-third at planting and two-third at panicle initiation	86	61
One-third at planting, one-third at tillering and one-third at panicle initiation	90	50

5. Conclusion

Time of nitrogen application was found to be one of the major rice yield limiting factors in Fogera plain where rice is grown year after year as mono-cropping. Split application of the full recommended nitrogen rate (69/10 kg N/P ha^{-1}) one-third at planting and two-third at tillering stage of rice crop was found to be the appropriate time of nitrogen application in Fogera Vertisols and gave 11% (437 kg/ha) grain yield increase over applying nitrogen fertilizer half at planting and half at tillering stage.

References

Aamer, I., G. Abbas and A. Khaliq. (2000). Effect of different Nitrogen application Techniques on the Yield and Yield Components of Fine Rice. *International Journal of Agriculture and Biology* 2(3):239–241.

Aragon, E.L., J.C. Calabio, J.L. Padilla, R.A. Shad, M.I. Samson, and S.K. De Datta. (1984). Fertilizer Management Under Different Systems of Rice Culture. *Philipp. J. Crop Sci., 9(2):105-116*.

Cassman, K.G., S. Peng, D.C. Olk, J.K. Ladha, W. Reichardt, Dobermann A. (1998). Opportunities for increased nitrogenuse efficiency from improved resource management in irrigated systems. *Field Crops Res*. 56: 7–39.

Castillo, E. (2006). Nutrient-use efficiency of rainfed lowland rice as affected by salinity and water stresses. Thesis (Ph.D), Chiba University, Japan.

CEDEP (Consultants on Economic Development and Environmental Protection). (1999). Amhara National Regional State (ANRS) – *Agricultural*

Research Master Plan.Vol.1 – main report. ANRS Bureau of Agriculture, Bahir Dar, Ethiopia.

Charles, E. (2003). Revised guide for rice fertilization. University of Arkansas, Rice Research and Extension Center.

Consuelo, M.P., O.J. Bienvenido, P.L. Samuel, M.A. Jovencio and Kenneth, G.C.(1996). Effects of late nitrogen fertilizer application on head rice yield, protein content, and grain quality of rice. Cereal chemistry,American Association of Cereal Chemists 73(5):556-560.

De Datta, S.K., R.J. Buresh, M.I. Samson and Kai-Rong W. (1988). Nitrogen use efficiency and nitrogen-15 balances in broadcast flooded and transplanted rice. *Soil Sci. Soc. Am. J.* 52: 849–855.

Dei Y. and S. Yamasaki. (1979). Effect of water and crop management on the nitrogen-supplying capacity of paddy soils. In: Nitrogen and Rice. International Rice Research Institute, Los Ban˜os, Philippines, pp. 451–463.

Dobermann, A. and T. Fairhurst. (2000). Rice: Nutrient disorders and management. International rice research Institute. Manila, Philippines.

FAO. (2005). Fertilizer use by crop in Egypt First version, published by FAO, Rome, 2005. Pp 33-35.

George I. (1980). Effects of level, time, and splitting of urea on the yield of irrigated direct seeded rice. *Plant and Soil* 56(2):209-215.

Haefele, S.M., K. Naklang, D. Harnpichitvitaya, S. Jearakongman, E. Skulkhu, P. Romyen, S. Phasopa, S. Tabtim, D. Suriya-arunroj, S. Khunthasuvon, D. Kraisorakul, P. Youngsuk, S.T. Amarante, and L.J. Wade. (2006). Factors affecting rice yield and fertilizer response in rainfed lowlands of northeast Thailand. *Field Crops Research* 98: 39–51.

Hatfield J.L. and J.H. Prueger. (2004). Nitrogen Over-use, Under-use, and Efficiency. "New directions for a diverse planet". Proceedings of the 4th International Crop Science Congress, 26 Sep – 1 Oct 2004, Brisbane, Australia. Pp 21-29.

Hussain, M Z, S.A Khan, T.M Thiyagarajan. (2009). Increasing Nitrogen Use Efficiency in Rice (Oryza sativa L.) with Chlorophyll Meter and Leaf Color Chart. *The IUP Journal of Soil and Water Sciences* 12:233-253.

James, E. and L. Stribbling. (1995). Fertilizer management to protect water quality. In: Agricultural and Natural resource water quality controlling. Alabama A & M and Auburan Universities.

Kissan-Kerala. (2007). Fertilizers Management. http://www.kissankerala.net/kissancontents/.jsp. 29/10/2007 12:53.

Linquist B. and P. Sengxua. (2003). Efficient and flexible management of nitrogen for rainfed lowland rice. *Nutrient Cycling in Agroecosystems. 67(2).* Kluwer Academic Publishers, the Netherlands. *Pp.107-115*.

Marqueses, E.P. H.F. Schnier, M. Dingkuhn, J.E. Faronilo, C.B. Javellana, J.E. Wijangco, and S.K. De Datta. (1988). Effects of timing and method of nitrogen application on grain yield, agronomic efficiency, plant nitrogen and dry matter yield in transplanted and direct seeded lowland rice [Philippines]. *Philippine Journal of Crop Science* 13:12-16.

Mushayi, P.T., S.R. Waddington and C. Chiduza. (1999). Low efficiency of nitrogen use by maize on small holder farms in sub-humid Zimbabwe. In: Maize production technology for the future: Challenges and opportunities, Proceddings of the sixth Eastern and Southern Africa Regional Maize Conference, Addis Ababa, Ethiopia: CIMMYT and Ethiopian Agricultural Research Organization. Pp. 278-81.

Ohnishi M., T. Horie, K. Homma, N. Supapoj, H. Takano and S. Yamamoto. (1999). Nitrogen management and cultivar effects on rice yield and nitrogen use efficiency in Northeast Thailand. *Field Crops Res*. 64: 109–120.

SAS Institute. (2002). Users guide, basic version 9.1 Edition. Carry, NC: SAS Institute, USA.

Sathiya, K. and T. Ramesh. (2009). Effect of Split Application of Nitrogen on Growth and Yield of Aerobic Rice. *Asian J. Exp. Sci. 23(1):303-306.*

Schnier H.F., S.K. De Datta and K. Mengel. (1987). Dynamics of N labeled ammonium sulfate in various inorganic and organic soil fractions of wetland rice soils. *Biol. Fert. Soils* 4: 171–177.

Stevens, G., S. Hefner and T. Gladbach. (2001). Effect of nitrogen timing and rates on tillering and yield of rice. *Soil Science and Plant analysis* 32: 421-428.

Tesfaye Zegeye, Befekadu Alemayehu and Aklilu Agidie. (2005). Rice production, consumption and marketing: The case of Fogera, Dera and Libokemkem Districts of Amhara Region. Paper presented on the National workshop on the status of rice research and promotion in Ethiopia. 3-4 June 2005, Bahir Dar, Ethiopia.

Tilahun Tadesse, Minale Liben, Alemayehu Assefa, Belesti Yeshalem and Tesfaye Wossen. (2007). Effect of nitrogen and phosphorus fertilizers on the yield of rice in Fogera and Metema areas. In: Ermiase A., Akalu T., Alemayehu A., Melaku W., Tadesse D., and Tilahun T. (eds.). *Proceedings of the 1st Annual Regional Conference on Completed Crop Research Activities, 14- 17 August 2006. Amhara Regional Agricultural Research Institute.* Bahir Dar, Ethiopia.

Zaheen, M., R.I. Ali, T. Awan, N. Khalid and M. Ahmad. (2006). Appropriate time of nitrogen application To fine rice, *Oryza sativa*. *J. Agric. Res.*, 44(4):261-266.

Zaheen, M., R.I. Ali, T. H. Awan, N. Khalid and M. Ahmad. (2006). Appropriate time of nitrogen application to fine rice, *Oryza sativa*. *J. Agric. Res*. 44(4):75-79.