Effect of Nitrogen Application Timing on Growth, Grain Yield and Nitrogen Use efficiency of Rice (*Oryza Sativa L)* in Fogera Plain, North Western Ethiopia

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Abstract:

*Nutritional management in rice (Oryza sativa L.) crops is mainly associated with N fertilization, which is difficult to adjust in field conditions due to variations in soil type and climatic conditions. A field experiment was carried out to determine the effect of time of nitrogen fertilizer application for increasing nitrogen use efficiency in lowland rice (Oryza sativa L.) Fertilizer rate of 69/23 kg N/P2O5 ha-^{1} and seven nitrogen application times was conducted on Vertisols of Fogera plain during 2016/2017and 2017/2018 cropping season. The treatments were 1/2 at sowing + 1/2 at tillering (control), 1/3 at sowing + 2/3 at tillering , 1/3 at 15 days after sowing + 2/3 at panicle initiation, 1/3 at 25 days after sowing + 2/3 at panicle initiation, 1/3 at sowing + 1/3 at mid tillering + 1/3 at panicle initiation, 1/3 at 15 days after sowing +1/3 at panicle initiation +1/3 at heading and 1/3 at 25 days after sowing + 1/3 at panicle initiation +1/3 at heading. RCB Design with three replications was used. The objective of the experiment was to select appropriate time of N fertilizer application for maximum rice yield in the study area. Results showed significant difference in Panicle length, Number of total tillers, Number of Fertile Panicles and Number of filled spicklets per Panicles but not in grain yield and straw yield in response to time of N application. The highest agronomic Nitrogen Use Efficiency (42.9) was recorded from 1/3 of N applied at 15 days after sowing + 2/3 of N at panicle initiation stage of the rice crop. The economic analysis showed that the highest net benefit of Birr **84776**. ha-^{1} was obtained from 1/3 of N at 15 days after sowing + 2/3 of the recommended Nitrogen fertilizer at panicle initiation stage of the crop, which is 17760.00 Birr more than the net Benefit obtained from the control treatment. Based on the economic analysis, the highest NB Birr **84776** ha-^{1} and highest grain yield (5.6 t/ha) was observed from the time of Nitrogen application one third of N 15 days after sowing and the remaining two third of the recommended nitrogen at Panicle initiation stage of rice crop was found to be the best and appropriate time of nitrogen fertilizer application for rainfed lowland rice production system of Fogera plain and other similar agro ecologies.*

Keywords: *Vertisol, Low land rice, grain yield, Panicle initiation, agronomic NUE*

1. NTRODUCTION

Rice (*Oryza sativa* L.) is one of the most popular cereal crops in the world. It is the most important food crop for the world's population, especially in South Asia, Middle East, Latin America and West India (Zhao *et al*., 2011). More than 90% of rice is produced and consumed in Asia (Subedi *et al*, 2019). It provides some 700 calories per person, mostly residing in developing countries. In Ethiopia, rice production was started three decades ago in the early 1970's and the country has reasonable potential to grow various rice types mainly in rain fed lowland, upland and irrigated ecosystems (Mulugeta and Heluf, 2014). Though rice is a recent introduction to the country, its importance is well recognized as the production area coverage of about 10,000 ha in 2006 has increased to over 63,000 ha in 2018 (CSA 2019).

Nitrogen (N) is one of the most important plant nutrients and plays a crucial role in increasing crop production and farm income. Nitrogen fertilizer consumption is increasing along with world crop production. However, more than 50 % of applied N is not assimilated by the rice plant, particularly when N fertilizer is applied using conventional broadcast methods. Most of the N not assimilated by the plant is lost through different mechanisms including ammonia (NH3) volatilization, surface runoff, and nitrification–denitrification and leaching (Dong et al. 2012; Rochette et al. 2013; Savant and Stangel 1990). Among these loss mechanisms, the most significant amount of loss occurs through NH3 volatilization which reaches up to 50 % of applied N (Sommer et al. 2004). These losses decrease N use efficiency (NUE) of conventional split broadcast prilled urea (PU) (Savant and Stangel 1990; Sommer et al. 2004).

The magnitude of losses by different mechanisms varies with soil and environmental conditions and with management practices regarding the time, rates and methods of applications. Losses of broadcast applied N increase with increasing N rates. Therefore, increasing N use has negative environmental consequences including nitrate pollution, eutrophication and emissions of greenhouse gas nitrous oxide and atmospheric pollutant nitric oxide (Gaihre et al. 2015; UNEP 2013, 2014). Alternative N fertilizer management strategies that increase crop productivity and NUE while reducing negative environmental consequences are needed. Management practices, therefore, should focus on optimum time, rate and placement methods that synchronize plant N requirements with N supply to reduce N losses and maximize uptake of applied N in the crop.

Concerning the time of application in Fogera area, all the recommended P2O5 and half of the recommended nitrogen should be applied at planting and half of the remaining nitrogen at tillering stage of the crop (Tilahun *et al.*, 2007). 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).

Application of N fertilizers at higher doses cause higher leaching loss. Leaching losses can be minimized by split application of nitrogenous simple fertilizer, application of complex/compound fertilizers in granular form, keeping the rice field's alternate wetting and drying, addition of organic matter to soil. Looking to the various types of losses of nitrogen, the nitrogen use efficiency of rice soil can be increased through right choice of source, right dose, right time and right method of application of N fertilizers along with proper water management practices (Sahu and Samant, 2006). By applying proper Nitrogen dose and applying the right time we can save money and can also keep our environment sound. Because the heavy use of fertilizer affects the soil and also the environment through the residual effect of fertilizer. Selection of the most appropriate time of nitrogen fertilization is a major concern of economic viability of crop production and the impact of agriculture. Therefore, the present study was undertaken to find out the appropriate nitrogen fertilizer application timing for better rice production in Fogera plain.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The Field experiment was conducted in Fogera plain, Ethiopia during 2016/2017 and 2017/2018 growing season. The experimental location, is situated at 11º46' to 11º59' latitude North and 37º33' to 37º52' longitude East at an altitude of 1815 meters above sea level (masl) (Tilahun *et al.*, 2012). The mean annual rainfall of the area is 1216 mm. Farmers depend on long rainy season (June to September) for crop production. The dominant soil type on the Fogera plains is black clay soil (ferric Vertisols) (Tilahun *et al.*, 2012). The experimental soil was clayey in texture with a pH of 6.05.

2.2. Experimental Design and Procedures

Recommended fertilizer rate of 69/23 kg N/P2O5 ha-^{1}was used in the experiment (Tilahun *et al.*, 2007). The Nitrogen was applied in seven different splits of nitrogen fertilizer application times. *1/2 at sowing + 1/2 at tillering (control), 1/3 at sowing + 2/3 at tillering , 1/3 at 15 days after sowing + 2/3 at panicle initiation, 1/3 at 25 days after sowing + 2/3 at panicle initiation, 1/3 at sowing + 1/3 at mid tillering + 1/3 at panicle initiation, 1/3 at 15 days after sowing +1/3 at panicle initiation +1/3 at heading and 1/3 at 25 days after sowing + 1/3 at panicle initiation +1/3 at heading. RCB Design with three replications was used.* The gross and net plot sizes were 4 m x 3 m (12 m2) and 3 m x 2 m (6 m2), respectively. To control mixing of treatments, experimental plots were bunded manually. For each treatment equal amount of phosphorous (23 kg P2O5 ha-^{1}) was applied during planting uniformly. The N fertilizer was side dressed with 5 cm distance from the plant to reduce the burning effect according to the time of nitrogen application. Variety X-Jigna was used as a test crop at the seed rate of 80 kg ha-1 in rows 20 cm apart. Data on Plant height, total numbers of tillers, number of effective tillers, panicle length, numbers of filled spikelets per panicle, number of un- filled spikelet's per panicle, biomass, straw and grain yield were collected from the net plot. The data were subjected to analysis of variance using Statistical Analysis System (SAS) Version 9.2 (SAS Inc., 2002). Agronomic Nitrogen Use Efficiency (ANUE) was calculated as extra kilogram of grain per extra kilogram of N applied (Mushayi *et al.*, 1999; Hatfield and Prueger, 2004).

3. RESULTS AND DISCUSSION

3.1 Panicle Length

Rice panicle length was significantly ($P<0.05$) responding to time of nitrogen application (Table 1). Maximum panicle length (20.1 cm) was recorded at (T3) with spilt application of 1/3rd of N 15 days after sowing and 2/3rd at Panicle initiation. The minimum panicle length of (17.7cm) was obtained from T1 and T2, which is statistically similar (Table 1). Panicle length due to T3 nitrogen application appeared because of the fact that nitrogen takes part in panicle formation as well as panicle elongation and for this reason, panicle length increased with the increase of N fertilization and time of split application of N at panicle initiation stage. application of 1/3 15 days after sowing and 2/3 at panicle initiation growth stage the role of nitrogen at might be speed up the formation of growth regulators such as auxines of hormones which increased the panicle exertion through increasing the internodes elongation located below the panicle. These findings are in agreement with those obtained by Arafat (2007) and El-Kallawy (2008).

3.2 Number of Fertile Panicle

The effect of split application of N fertilizer on number of Fertile Panicles per meter row length appeared to be considerable at (T3) The highest number of Fertile Panicles per row meter length (77.0) were recorded from Split application 1/3 of N at 15 days after sowing plus 2/3 of the recommended N at panicle initiation stage of rice (Table 1). The lowest number (62.0) of Fertile Panicles per meter row length was recorded from split application of 1/2 of the recommended N at planting and the remaining 1/2 at tillering stage of the crop (Control treatment). (Table1). These results indicated that application of nitrogen consecutively according to plant N-demand at physiological growth stages especially at the beginning of flowering significantly increased panicles/m² by reducing mortality percentage and stabilized panicles/m² at a constant during reproductive stage. The same trend was found by Edwin *et al.* (2004), Mohammed (2006) and El-Kallawy (2008)

3.3 Number of Un-filled spicklets per panicle

The effect of time of nitrogen fertilizer application was statistically significant ($P<0.05$) on number of un-filled spikelets per panicles but not statistically significant on number of filled spicklets per panicle (Table 1). Minimum number of un-filled spikelet per panicle (5.0) was observed at (T3) N application of 1/3 at 15 days after sowing and 2/3 at panicle initiation, while maximum number of un-filled spikelets per panicle (15) was observed in T1and T2 (Table 1). Nitrogen fertilization improved growth and increased the assimilate products by enhancing the source and sink consequently, resulting in more filled grains against unfilled grains/ panicle. The obtained data related to number of filled grains/ panicle completely agreed with t Mikhael (2010). This result is also in agreement with Fallah, (2012) and Ehsanullah *et al*., (2001) who reported that nitrogen promotes rapid growth and increased spikelet number per each panicle. The findings of Witt *et al*., (2007) indicated 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) per panicle that developed in to increased grain number per panicle.

3.4 Number of tillers per row meter Length

Significant difference in tiller production per row meter length was observed due to split application of N fertilizer (Table 1). The highest number of total tillers per row meter length (80.0) were produced when nitrogen fertilizer was applied in (T3) 1/3 of N at 15 days after sowing plus 2/3 of the recommended N at panicle initiation stage of rice (Table 1) The smallest number of total tillers per row meter length (64.0) was produced when time of nitrogen fertilizer was applied half of the recommended N at planting and the remaining half at tillering stage of the crop (Control treatment). This result might be due to nitrogen promotes formation of the different organs in the rice plant as well as other physiological processes. N is the major component for the development of tillers, leaves and grains and promotes protein and carbohydrate synthesis. This is supported by Vennila *et al.,* (2007) who reported that productive tillers were effectively increased with fertilizer N application. According to Yoshida *et al*. (1972) as the amount of nitrogen absorbed by the crop increases, there is an increase in the number of tillers per square meter.

4.0 Effects of Time of Nitrogen Fertilizer Application on Nitrogen Use Efficiency

Nitrogen use efficiency\ (NUE) was estimated as grain yield advantage divided by the N application rate. (Cassman *et al.,* 1996; Nielsen RN 2006).It is a parameter that excludes contributions to N-use efficiency\ from indigenous N of the soil-floodwater system Applied fertilizer Nitrogen is partly taken up and used by the crop and partly loss to the environment. Nitrogen Use efficiency is a term used to indicate the relative balance between the amount of fertilizer N taken up and used by the crop versus the amount of fertilizer N lost. 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 The optimum use of N can be achieved by matching supply with crop demand (Hussain *et al.,* 2009). Use of

N fertilizers in adequate amount, form, time and methods of application are important management strategies for rice production. The highest agronomic Nitrogen Use Efficiency (42.9) was recorded from 1/3 of N applied at 15 days after sowing + 2/3 of N applied at panicle initiation stage of the rice crop as compared to the other treatments. The lowest ANUE was observed in T1 (33.7) when nitrogen was applied half at planting and the other half at tillering (control) (Table 2). The specified treatment (T3) gave 42.9% ANUE for the rates of 69 kg/ha N compared to the control treatment (33.7). Application of one-third of N at 15 days after sowing + two third at panicle initiation stage gave 9.2% ANUE advantage over the control.

5.0 Economic Analysis

Based on the principles of economic analysis CIMMYT (1988), the minimum acceptable marginal rate of return (MRR %) should be 100%.The economic analysis was done on the basis of the prevailing prices of variable costs using the Ethiopian currency (Birr). The price of NPS and Urea fertilizer was 1430.00 and 1310.00 Birr per 100 kg respectively. Moreover, the price of rice straw valued birr 120.00 per 100 kg. In addition to this, the prices of seed for planting material and labour cost for fertilizer application during the cropping season were 1350.00 birr per 100 kg and 80 birr for man days respectively. Grain and straw yields adjustments, calculations of total variable costs (TVC), gross benefits (GB) and net benefits (NB) were performed (Table 3). Unlike that of the physical agronomic yield, the economic analysis of the combined result of the experiment with two years (Table 3) revealed that the profitable highest mean net benefit of (Birr **84776**. ha-^{1}) was obtained from time Fertilizer application 1/3 of N at 15 days after sowing + 2/3 of the recommended Nitrogen fertilizer at panicle initiation stage of the crop, which is 17760.00 Birr more than the net Benefit obtained from the control treatment (1/2 of N applied at planting and the remaining 1/2 of the recommended N at tillering stage of the crop) Table 3 Dominance analysis was performed after arranging the treatments in their order of TVC. Treatments are considered as dominated if it has higher TVC but lower NB than a previous treatment with lower TVC and higher NB (Table 4). Marginal rate of return (MRR) were not computed because of all the treatments were dominated except Treatment 3 (Applying 1/3 of N at 15 days after sowing + 2/3 at panicle initiation) (Table 4). Highest net benefit of (Birr **84776**. ha-^{1}) was observed from (T3) 1/3 of N at 15 days after sowing + 2/3 at panicle initiation stage of the crop is the most profitable treatment of Nitrogen application time to be recommended for rice production in Fogera plain.

6.0 SUMMERRY AND CONCLUSION

Nitrogen is the most important nutrient needed throughout the growth stages of the rice plant, from seedling up to maturity, for vegetative growth as well as for yield production. 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. From the findings of the present experiment, highest mean net benefit of (Birr **84776**. ha-^{1}) was obtained from Fertilizer application 1/3 of N at 15 days after sowing + 2/3 of the recommended N fertilizer at panicle initiation growth stage of rice, which is 17760.00 Birr more than the net Benefit obtained from the control treatment (1/2 of N applied at planting and the remaining 1/2 of the recommended N at tillering stage of the crop) Based on the economic analysis it can be conclude that that split application of nitrogen one third at fifteen days after sowing plus two third of N at panicle initiation stage of rice crop was found to be the best appropriate time of nitrogen fertilizer application for rained lowland rice production in Fogera plain and other similar agro ecologies.

Table 1:*-Effects of Time of Nitrogen application on yield and Yield components of Rice*

Trts	Ph (cm)	Pl (cm)	Ntt/rml	Nfp/rml	Nfs /p	Nus/p	Gy (t/ha)	Sy (t/ha)	Tgw(g)	HI (%)
T1	84.4	17.7b	64b	62b	65	15a	4.4	8.9	25.3	34.0ba
T2	89.8	17.7b	72ba	69ba	77	15a	4.8	11.5	26.2	30.8b
T3	91.0	20.1a	80a	77a	83	5c	5.6	10.2	27.4	37.1ba
T4	88.2	19.4ba	72ba	69ba	69	15a	4.8	10.0	26.9	34.2ba
T5	88.6	18.5ba	76ba	74ba	78	6bc	5.3	9.1	25.4	41.7a
T6	85.9	19.2ba	68ba	65ba	66	12ba	4.9	7.4	26.0	39.6ba
T7	91.0	18.9ba	64b	62b	76	15a	4.7	9.6	26.6	33.5ba
Sig. diff.	NS	*	*	*	NS	**	NS	NS	NS	*
SE±	6.69	1.56	11.07	11.51	27.7	4.47	1.53	3.93	2.88	7.26
CV	7.59	8.30	15.63	16.85	20.4	41.44	31.00	41.29	10.96	20.26

Means in the column with the same letter are not significant different at 1%, 0.1% and 5% probability level. ***CV****= Coefficient variance;* ***LSD****=Least significant difference;* ***SE****=Standard error;* ***Ph****= Plant height;* ***Pl****=Panicle length(cm);****Ntt /rml****=Number of total tillers per row meter length;* ***Nfp/rml****=number of fertile panicles per row meter length;* ***Nfs/p****=Number of filled spicklets per panicle;* ***Nus/p****=Number of un-filled spicklets per panicle;* ***Gy(t/ha)****=Grain yield ton per hectare ;* ***Sy(t/ha)****=Straw yield ton per hectare;* ***Tgw****=Thousand grain weight in gram and* ***HI%****=Harvest Index in percent;;* ***T1****=1/2 at sowing + 1/2 at tillering ,representing the control* ***T2****=1/3 at sowing + 2/3 at tillering,****T3****=1/3 at 15 days after sowing + 2/3 at panicle initiation,****T4****= 1/3 at 25 days after sowing + 2/3 at panicle initiation,****T5****= 1/3 at sowing + 1/3 at mid tillering + 1/3 at panicle initiation,* ***T6****= 1/3 at 15 days after sowing +1/3 at panicle initiation +1/3 at heading and* ***T7****=1/3 at 25 days after sowing + 1/3 at panicle initiation +1/3 at heading.*

Tabl3e2. *Effects of Split application of Nitrogen Fertilizer on Agronomic Nitrogen Use Efficiency (ANUE) of Rice*

Time of Nitrogen fertilizer application	**ANUE at 69 kg of N/ha**
T1 =1/2 at sowing + 1/2 at tillering ,(control)	33.7
T2 =1/3 at sowing + 2/3 at tillering,	36.8
T3 =1/3 at 15 days after sowing + 2/3 at panicle initiation	**42.9**
T4 = 1/3 at 25 days after sowing + 2/3 at panicle initiation,	36.8
T5 = 1/3 at sowing + 1/3 at mid tillering + 1/3 at panicle initiation,	40.6
T6 = 1/3 at 15 days after sowing +1/3 at panicle initiation +1/3 at heading	37.6
T7 =1/3 at 25 days after sowing + 1/3 at panicle initiation +1/3 at heading	36.0

Table 3 *Grain and straw yield adjustments, total variable cost, gross and net benefit analysis*

Treatments	**N kg/ha**	**P_2O_5kg/ha**	**GY t/ha**	**ST t/ha**	**AGY**	**ASY**	**GB**	**TVC**	**NB**
T1	69	23	4.4	8.9	3960	8010	70080	3063.63	67016.4
T2	69	23	4.8	11.5	4320	10350	78600	3063.63	75536.4
T3	**69**	**23**	**5.6**	**10.2**	**5040**	**9180**	**87840**	**3063.63**	**84776.4**
T4	69	23	4.8	10	4320	9000	76800	3063.63	73736.4
T5	69	23	5.3	9.1	4770	8190	82470	3383.63	79086.4
T6	69	23	4.9	7.4	4410	6660	75030	3383.63	71646.4
T7	69	23	4.7	9.6	4230	8640	74970	3383.63	71586.4

T1*=1/2 at sowing + 1/2 at tillering ,representing the control* ***T2****=1/3 at sowing + 2/3 at tillering,****T3****=1/3 at 15 days after sowing + 2/3 at panicle initiation,****T4****= 1/3 at 25 days after sowing + 2/3 at panicle initiation,****T5****= 1/3 at sowing + 1/3 at mid tillering + 1/3 at panicle initiation,* ***T6****= 1/3 at 15 days after sowing +1/3 at panicle initiation +1/3 at heading and* ***T7****=1/3 at 25 days after sowing + 1/3 at panicle initiation +1/3 at heading. TVC= Total variable cost (Birr ha-^{1}) GY, Average grain yield (t ha-^{1}) AGY= Adjusted grain yield (ton ha-^{1}); SY=Average straw yield (ton ha-^{1}) ASY= Adjusted straw yield (ton ha-^{1}); GB= Gross benefit (Birr ha-^{1}); NB = Net benefit (Birr ha-1)*

Table 4 Dominance analysis for TNA for grain yield of low land rice at Fogera

Time of Nitrogen fertilizer Application	N kg/ha	P2O5 kg/ha	TVC	NB	Dominance
1/2 at sowing + 1/2 at tillering ,(control)	69	23	3064	67016	D
1/3 at sowing + 2/3 at tillering,	69	23	3064	75536	D
1/3 at 15 days after sowing + 2/3 at panicle initiation	**69**	**23**	**3064**	**84776**	
1/3 at 25 days after sowing + 2/3 at panicle initiation,	69	23	3064	73736	D
1/3 at sowing + 1/3 at mid tillering + 1/3 at panicle initiation,	69	23	3384	79086	D
1/3 at 15 days after sowing +1/3 at panicle initiation +1/3 at heading	69	23	3384	71646	D
1/3 at 25 days after sowing + 1/3 at panicle initiation +1/3 at heading	69	23	3384	71586	D

TVC= Total variable cost (Birr ha^{-1}); NB= Net benefit (Birr ha^{-1})

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