Split application of nitrogen fertilizer for lowland rice production on Vertisols of Fogera plain

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Abstract

Complete factorial combinations of two economically feasible nitrogen fertilizer rates (69/23 and 46/46 kg N/P_2O_5 ha^{-1}) and five levels of split nitrogen fertilizer application times (half at sowing + half at tillering representing the control; half at sowing + half at panicle initiation; one-third at sowing + two-third at tillering; one-third at sowing + two-third at panicle initiation; and one-third at sowing + one-third at tillering + one-third at panicle initiation) were compared in RCBD with three replications at four sites. The objective was to determine the optimum time of split nitrogen fertilizer application for improving productivity of lowland rice on Vertisols of Fogera plain. First and second order interactions of site-year environments, N rates and timing of N split applications did not significantly affected grain yield response of rice. The main effects of N rates also had no significant grain yield difference. But, the main effects of N split application times significantly ($p<0.05$) affected grain yield. Split application of N at one-third at sowing and two-third at tillering stage was the highest yielding (4409 kg ha^{-1}) and is recommended for lowland rice production in the Vertisols of Fogera plain.

Key words: Nitrogen fertilizer, rice, split application.

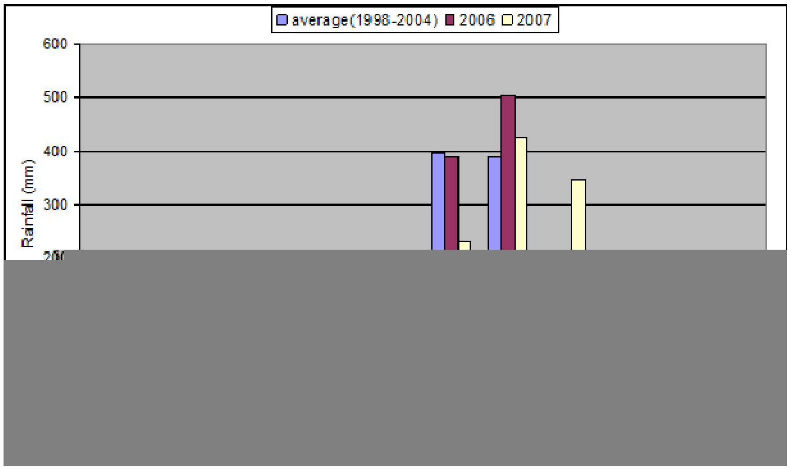
Introduction

Rice (*Oryza sativa* L.) is an important food crop of the world. In Ethiopia, rice has become one of the most important crops where its production and area coverage have been increasing, especially in the Fogera plain (Tesfaye *et al.*, 2005). Research activities have been going on so as to improve productivity and production of rice in the Fogera plain. 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 (Tilahun *et al.*, 2007) where rice was grown every year as monocrop. Experiences elsewhere also show that most crop plants recover only 25-35% of the nitrogen applied as fertilizers. Losses occur by ammonia volatilization, denitrification, immobilization to organic forms, leaching, and runoff (Kissan-Kerala, 2007). Increasing the congruence between crop N demand and N supply improves N use efficiency in lowland rice (Cassman *et al.*, 1998). One of such options is split application of nitrogen fertilizer that was reported to show increased rice yield (Zaheen *et al.*, 2006). The increase in grain yield with increasing number of N splits might be due to increased nitrogen uptake efficiency and reduction in nitrogen losses (James and Stribbling, 1995). Generally, recommendations on number of N fertilizer splits depend on factors like rice variety, yield goal, total amount of nitrogen to be applied, soil type, climate and crop rotation (James and Stribbling, 1995). Thus, there are numerous reports that recommend different nitrogen fertilizer application splits for rice production. Charles (2003) recommended two splits application where the first split is applied at planting and the remaining at internodes elongation. Stevens *et al.* (2001) recommended three split applications at basal, at early-maximum tillering and at panicle initiation. Consuelo *et al.* (1996) also recommended that nitrogen fertilizer should be applied in four splits at basal, maximum tillering, panicle initiation and flowering. This study was, therefore, conducted to determine the optimum time of nitrogen fertilizer application to improve productivity of rice in the Fogera plain.

Materials and methods

The study area

This experiment was conducted on the Vertisols of the 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). Fogera plain is located in the South Gondar Administrative Zone at an altitude of 1910 meter above sea level. The nine years (1998-2004, 2006 & 2007) mean annual rainfall in the area is 1317 mm. Based on the data from Addis Zemen meteorology station, which is at vicinity of experimentation area, four years (2004-2007) mean monthly maximum and minimum temperature is 29.8 ^{O}C and 9.4 ^{O}C, respectively. The soil textural class is 67% clay, 25% silt and 8% sand, with a soil pH of 5.8 (Yihenew, 2002). The annual rainfall distribution is indicated in Figure 1.



Experimental design and procedures

The experiment was conducted in four sites (one site in 2006 and three sites in 2007) under rainfed conditions. Complete factorial combinations of two economically feasible fertilizer rates (69/23 and 46/46 kg N/P_2O_5 ha^{-1}) and five splits of nitrogen fertilizer application times (half at sowing + half at tillering representing the control; half at sowing + half at panicle initiation; one-third at sowing + two-third at tillering; one-third at sowing + two-third at panicle initiation; and one-third at sowing + one-third at tillering + one-third at panicle initiation) were laid out in RCBD with three replications at each site. The gross and net plot sizes were 4 m x 3 m and 3 m x 2 m, respectively. All the phosphorus fertilizer rates were applied at sowing. Variety *X-Jigna* was broadcast sown at the seed rate of 100 kg ha^{-1}. Grain yield, fertile panicle number, thousand grain weight, and plant height data were subjected to analysis using SAS by considering the four site-year environments as random variable.

Results and discussion

The analysis of variance for individual sites indicated that significant grain yield differences in response to time of nitrogen application were observed only in two of the four sites (Table 1). Significant differences in response to nitrogen fertilizer rates and fertilizer by time of application interaction effects were observed in none of the sites. The main effect of applying nitrogen fertilizer at one-third at sowing and two-third at tillering gave the highest yield with a yield advantage ranging from 1 to 24% over the control.

Table 1. Analysis of variance for grain yield of rice at each site on 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 (T_1)	4309	3872	2912	4796
Highest mean yield (kg ha^{-1})	5353	4142	2940	5203
Time of N application for highest mean yield	T_3	T_3	T_3	T_3
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 at 5 % level of significance; T_1 = N applied half at planting + half at tillering (control), T_3 = N applied one-third at planting + two-third at tillering.*

Combined analysis over four environments of site-year combinations revealed that first and second order interactions of nitrogen rates with time of applications and environments were not significant for gain yield and other parameters (Table 2). First and second order interactions of environments with nitrogen rates and application times were also not significant for grain yield, indicating that no need for environment specific recommendation. The main effects of nitrogen fertilizer rates were also not significant for grain yield and other parameters as opposed to the main effects of time of applications that showed significant ($p<0.05$) grain yield difference (Table 2).

The highest significant grain yield of 4409 kg ha^{-1} was obtained when nitrogen was applied one-third at sowing and two-third at tillering (Table 3). The lowest yields of 3767 and 3772 kg ha^{-1} were obtained when nitrogen was applied half at sowing and half at panicle initiation, and one-third at sowing plus one-third at tillering plus one-third at panicle initiation, respectively (Table 3). The result indicated that relatively higher amount of nitrogen should be applied at tillering than at sowing or at panicle initiation so as to increase the number of grains and subsequently higher grain yield.

Table 2. Combined analysis of variance over four site-year environments for grain yield and some yield components of rice grown on the Vertisols of Fogera plain.

Source of variation	Grain yield (kg ha^{-1})	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

**, ** and NS denote significant differences at 5 and 1% level of significance and none significant difference, respectively.*

This finding is in line with Cassman *et al*. (1998) who claimed that a greater portion of the N requirement should be applied during active tillering stage at which 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 available from the mineralization of organic matter is greatest during this phase (Dei and Yamasaki, 1979) and should be adequate to meet crop needs during the early growth stage.

Table 3. Grain yield of rice as affected by nitrogen fertilizer rates and split application times on the Vertisols of Fogera plain, combined over four site-year environments.

Time of N split applications	Fertilizer rates (kg ha^{-1}) 46/46 N/P_2O_5	Fertilizer rates (kg ha^{-1}) 69/23 N/P_2O_5	Mean*
Half at sowing and half at tillering (control)	4001	3944	3972^{b}
Half at sowing and half at panicle initiation	3899	3635	3767^{b}
One-third at sowing and two-third at tillering	4357	4462	4409^{a}
One-third at sowing and two-third at panicle initiation	3961	4215	4088^{ab}
One-third at sowing, one-third at tillering and one-third at panicle initiation	4120	3425	3772^{b}
Mean	4067	3936	

**Values followed by the same letter in a column are not significantly different at 5% probability level of significance.*

The current result also revealed that application of nitrogen in two splits is preferable than three splits and gave yield advantage of 637 kg ha^{-1} (16.8 %). This is in agreement with a lot of results (George, 1980; Haefele *et al.*, 2006; Marqueses *et al.*, 1988) which recommended two split applications of N fertilizer for rice production. Though number of authors recommended two split applications, there is variation in the timings of nitrogen fertilizer split applications for rice. Marqueses *et al.* (1988) reported that application of one-third N band placed at 20 days after sowing and two-third N at 5-7 days before panicle initiation gave significantly higher grain yields (8.5 t ha^{-1}) and agronomic efficiency (60 kg grain per kg N applied). The results of George (1980) showed that two split applications given at maximum tillering and panicle initiation stages gave higher grain yield than three splits applied at 10 days after rice emergence, maximum tillering and panicle initiation stages. Haefele *et al.* (2006) also recommended two split nitrogen fertilizer applications at basal and panicle initiation for rainfed lowland rice production in Thailand.

Conclusion and Recommendations

The results of this experiment revealed that split nitrogen fertilizer application timing is one of the important management factors for improving lowland rice productivity and production on the Vertisols of Fogera plain, where rice has been grown as monocrop. Split application of one-third at sowing and two-third at tillering stage of rice was the highest yielding among the tested split application time treatments. Therefore, split application of nitrogen with one-third at sowing and two-third at tillering stage is recommended for rice production on the Vertisols of Fogera plain, as it gave 11% yield advantage (437 kg grain ha^{-1}) over the control.

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