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Growth and Yield of Rice (*Oryza sativa* L.) as Affected by Time and Ratio of Nitrogen Application at Jimma, South-West Ethiopia

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Abstract **– Insufficient nitrogen supply in inappropriate timing is an important constraint to productivity of upland rice (*Oryza sativa* L.), and there is limited information available on optimal timing of N application for upland rice in Ethiopia including Jimma area. Field experiment was conducted on three upland rice varieties (Gumara, Ediget and Nerica-4) in a completely randomized block design with 3 replications to determine the effects of timing and ratio of nitrogen application on growth and yield during the 2014 cropping season on acidic nitisol (soils possessing nitic property) at the Jimma University, College of Agriculture and Veterinary Medicine research site. The N-timing treatments were: N_1 (50% at sowing and 50% at active tillering stage), N_2 (25% at sowing + 50% at active tillering stage and 25% at panicle initiation), N_3 (25% at sowing + 25% at active tillering stage and 50% at panicle initiation), and N_4 (33% at sowing + 33% at active tillering stage and 33% at panicle initiation). The highest grain yields (1070 kg/ha), biomass yields (3333 kg/ha), total number of grains per panicle, and harvest index were recorded from 'Ediget' variety at the N_2 combination (25% at sowing + 50% at active tillering stage and the remaining 25% at panicle initiation), followed by N_3 and N_4 combinations. The lowest grain yields (117 kg/ha) and biomass yields (767 kg/ha) were recorded from Nerica-4 variety at the N_2 combination. Nerica-4 variety produced minimum grain and biomass yields across all the N combinations. Most of the parameters exhibited maximum performance under N_2 and N_3 combinations across all the varieties. The varietal treatments had highly significant ($P<0.001$) effects on the total number of panicles, grain yield, biomass yield and harvest index. Grain yield was positively correlated ($P<0.01$) with plant heights ($r=0.68^{**}$), number of filled grains per panicle ($r=0.52^{**}$) and thousand grains weight ($r=0.61^{**}$) and negatively correlated with most of the traits. Number of panicles was the most important component of yield, accounting for about 87% of the variation in rice yield. Thus, rice cultivation and its nitrogen fertilizer management in the area is concerned, the variety 'Ediget' was recommended for higher grain and biomass yields regardless of the N-timing treatments. Concerning the N-timing treatments, the farmers can use any of the N-timing types whichever they like.**

Keywords **– Nitrogen Fertilizer, Split Nitrogen Application, Rice, Timing of Nitrogen.**

I. Introduction

Rice belongs to the grass family. It is a vital food crop because half the world's population feeds rice as a main part of their diets. It provides more calories per hectare than any other cereal grain. In Ethiopia, rice is a highly valued crop and is primarily grown for its grains.

Rice is 2nd in area basis and total production in the world after wheat (FAOSTAT, 2012). In Ethiopia, rice is cultivated on an area of about 30,600 hectares (CSA, 2012). Further it has been reported that 4% of the total cereal crops production in the country is contributed by rice. Despite the above mentioned importance and coverage of an area, its productivity is very low. The average national yield of rice is less than 1 ton/ha. Some of the factors contributing to low yield of rice are: lack of high yielding cultivars, lodging, weed infestation, water logging, low moisture and fertility conditions (Taddesse, 2009).

The profitability of rice production system depends not only on crop breeding research but also on crop management technologies that enhance resource or input use efficiency. In Ethiopia, low soil fertility arose from continuous cropping, overgrazing, high soil erosion and removal of field crops' residues are among the major constraints affecting rice productivity (Kebebew *et al.*, 2002). Thus, to increase the productivity of rice, devising efficient crop improvement programs and appropriate agronomic management practices like improved soil fertility management is essential. The objective of nutrient management is to use nutrients (mainly N, P and K) wisely for optimal economic benefit to the farmer while minimizing impact on the environment. Nutrients are essential for the growth of crops and must be supplied to plants in adequate amounts to achieve satisfactory yields and profits. Excessive application of fertilizers or manure can contribute to pollution of streams, ground water resources and generally reduce profitability (Mulugeta *et al.*, 2011). When commercial fertilizers are applied at rates that exceed the plants' ability to remove the nutrients at a given growth stage, fertilizer run-off can occur. This runoff may be harmful to nearby water resources and is a waste of fertilizer. As a nutrient plan is developed, the long term balance of soil fertility, plant uptake, and removal of nutrients and the potential losses of nutrients to the environment should be considered. An appropriate goal for the nutrient plan is to maintain a productive and fertile farm (Patra *et al.*, 1992).

For obvious economical and environmental reasons, N application must be managed very carefully. When N is supplied from a fertilizer or other sources (manure, sewage sludge, etc), it should be applied at a rate that does not greatly exceed the expected crop N requirement. It should be applied as near as possible by the time when the plant need to reduce the chance for potential losses and to prevent undue nutrient enrichment of the environment

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(Taddesse, 2008). In Ethiopia, it is a common practice to apply nitrogen to the seedbed of rice when the efficiency of uptake by the plant can be low due to the scanty root system. Nitrogen could, therefore, be lost through leaching and volatilization. Moreover, applying N to very young seedlings could lead to unnecessary vegetative growth, which may result in increased susceptibility to shoot fly and lodging; and hence reduced grain yield.

As far as the status and potential of crop production in Jimma and its surrounding is concerned, the area is abounded with innumerable types of lucrative food and commercial crops. Major crops grown, other than coffee, are cereals (maize, tef), pulses (beans and peas), root crops (enset, potato and taro) among which maize and taro are the major sources of daily subsistence while coffee is mostly used for cash crop in the area. Enset is a strategic crop substantially contributing to the food economy of the area. Upland rice is the rice grown on flat well drained soils, without water accumulation in the field during crop growth cycle and totally depends on rainfall for water requirements. So far in the past, some adaptation trials on various rice genotypes have been conducted in the area. In line with this, Mulugeta *et al*. evaluated 14 rice genotypes against their grain yields along an altitude gradient in South Western Ethiopia in 2011. According to their evaluation, NERICA-4 and NERICA-3 rice varieties were recommended for rice producing farmers with in an altitude range of below 1500 m a. s. l. to maximize rice grain yields in Southwest Ethiopia and other similar areas. However, regarding the crop agronomic practices and others, a lot remains to be addressed. Moreover, as the crop is recently introduced to Ethiopia, its breeding and other agronomic researches are found at infant stage. Hence, it is important to carry out researches on a crop production packages particularly on nitrogen fertilizer and its optimal timing (Mulugeta *et al*., 2011).

With this understanding, it is indispensible to examine the fertilizer application practice to maximize use efficiency of N and hence to increase yield of rice. This experiment is, therefore, initiated with the aim to determine appropriate split N application for rice genotypes at the Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) research site. Therefore, the research was proposed with the following objective:

To determine appropriate time and ratio of nitrogen application on three rice genotypes under the agro-ecological conditions of the area.

II. Materials and Methods

The experiment was conducted at Eladale research site of the College of Agriculture and Veterinary Medicine, Jimma University, Ethiopia in 2013 and 2014 main cropping season. The area is located at 7^0 42' N latitude and 36^o48' E longitudes and at about 7 km far from Jimma town. The altitude of the experimental site is 1813 m a.s.l. The climate of the area is characterized by a long rainy season (May to September) accounting for about 85% of the annual rainfall having a peak falls in August. The average annual rainfall amounts to 1580 mm in which the length of growing period ranges between 130-150 days. The longer rainy seasons generally have more rainfall and are more reliable than the shorter rainy season (March-April). The dry season occurs between November and February. In recent years, however, the area has experienced a great variability in terms of occurrence and amount of rainfall causing crop failures on several occasions (personal observation).

The experimental materials used were three rice genotypes (Gumara, Ediget and Nerica-4), Urea and DAP fertilizers. All the rice genotypes were introduced primarily from IRRI (International Rice Research Institute) and WARDA (West Africa Rice Development Association) and evaluated at different locations of the country and released in different years (JICA, 2004).

The three rice genotypes were examined against the various N-timing combinations. Nerica-4 is a recommended rice genotype in the area according to the previous reports (at Seka and Serbo). All the genotypes perform well in altitude ranging between 1740-1900 m and rainfall range of 1200- 1520 mm. The NERICA (New rice for Africa) genotype was introduced from WARDA whereas Gumara and Ediget were introduced from IRRI (JICA, 2004).

2.1. The treatments

Rice genotypes

Three different rice genotypes were examined (Ediget, Gumara and Nerica-4).

N-timing treatments

The different combinations of split N applications were arranged as follows. Granular Urea fertilizer (46% N) at a rate of 64 kg/ha was top dressed at the various growth stages of the crop as indicated below.

1. 50% at sowing and 50% at active tillering stage............... ....N_1
2. 25% at sowing + 50% at active tillering stage and 25% at panicle initiation.............N_2
3. 25% at sowing + 25% at active tillering stage and 50% at panicle initiation.............N_3
4. 33% at sowing + 33% at active tillering stage and 33% at panicle initiation............ N_4

Active tillering stage occurred 34 days after emergence of the crop whereas panicle initiation occurred around 56 days from sowing. As Nerica-4 is the recommended rice variety in the area based up on the previous studies, this variety at N_1 (½ at sowing and ½ at active tillering stage) was taken as a check. The treatment includes factorial combinations of three rice genotypes along with the various ratios and timing of N.

2.2. Experimental Design and Plot Size

The experiment was laid out in a randomized complete block design (RCBD) with factorial arrangement in 3 replications. Each plot was 2 m long and 1.5 m wide and had a total size of 3 m^2 with 6 rows spaced 25cm. Seeds were sown on rows with manual drilling at a rate of 60 kg/ha.

2.3. Field Management Practices

Full basal dose of DAP granule fertilizer at a rate of 46 kg/ha P_2O_5 (20 kg/ha P) which is a blanket national recommendation was applied at sowing to all the plots uniformly to minimize plant phosphorus deficiencies. Weeds were removed by hand weeding three times (at early tillering, maximum tillering, and booting stages). No insecticide or fungicide was applied since no serious insect or disease incidences were occurred. Harvesting was done manually using hand sickles.

2.4. Soil Sampling and Analysis for Selected Physical and Chemical Properties

Surface soil samples (app. 0-30 cm) were collected randomly in a zigzag pattern before sowing from the entire experimental field of 20 spots and composited then analyzed in the laboratory for selected chemical and physical properties. The soil samples were analyzed for its pH, particle size distribution, organic matter contents, total nitrogen, and available phosphorus.

2.5. Data Collection and Analysis

2.5.1. Phenological data

Days to 50% heading and 90% physiological maturity was recorded through visual observation.

2.5.2. Growth, yield and yield related parameters

Observation and data record for all traits studied was made based on the Standard Evaluation System for rice (IRRI, 2002). Plant height, Tillers/plant, Panicles per plant, number of grains per panicle and panicle length were measured before physiological maturity from randomly selected 10 sample plants in the middle three rows of each plot. Grain yield was measured at harvest maturity by harvesting the 3 central rows of each plot and adjusted to grain moisture content of 14%. Thousand grains weight was determined from bulked grain samples in each plot and recorded on 14% seed moisture content basis. Biomass yield and harvest index were measured during the course of the study.

2.5.3. Data Analysis

After having test of homogeneity of variances for each traits studied, data were subjected to analysis of variance using statistical software package (SAS 9.1.3). Thus, combined analysis of variance of the two-year data was performed. The differences between treatment means were compared using least significance difference (LSD) test at 5% level of significance. Simple correlation coefficients were carried out for the yield and yield related parameters using the same software.

III. Results and Discussion

3.1. Soil Physical and Chemical Properties of the Study Site

The pre-sowing soil analysis showed that the experimental soil has a pH (H_2O) of 5.82 (moderately acidic). FAO (2008) reported that the preferable pH ranges for most grain crops and productive soils are in between 4 and 8. Thus, the pH of the experimental soil is within the range of productive soils and suitable for rice cultivation. Textural class of the soil is clay loam having compositions of 33% clay, 38% silt and 29% sand, which is in the textural class of clay loam in which is suitable for rice as well as for other agricultural crops according Tekalign Tadesse (1991).

Total nitrogen and organic matter content of the experimental site soils were 0.21% and 4.1 mg/kg, respectively (Table 1). According to Dewis and Freitas (1970), the nitrogen and organic matter contents of the soils are medium and high, respectively. As the research site was previously covered by other grain crops and continuously fertilized, the nitrogen and organic matter contents of the soil was found to be in medium to high range. Available phosphorus of the soils was 4.65 ppm (Table 1) and according to Landon (1991), the experimental soil is found to be very low and deficient in phosphorus as the area receives heavy rainfall, P is probably fixed by high concentrations of iron and aluminium. In general, the experimental soil was found to be conducive for rice cultivation.

Table 1: Selected physical and chemical properties of the experimental soil

Parameter	Value	Methods	Status
Particle size distribution (%)		Pipette Method	
Sand	29%		
Silt	38%		
Clay	33%		
Textural class			Clay loam
pH in 1:2.5 soils to water suspension	5.82	Glass Electrode pH Meter	Moderately acidic
Organic matter (mg/kg)	4.1	Walkley and Black method	High
Available phosphorus (ppm)	4.65	Bray method	Low and deficient
Total nitrogen (%)	0.21	Micro Kjeldahl method	Medium

3.2. Effects of applied N-timing treatments and genotypes on crop phenological events, growth parameters yield and yield related traits

The results of analysis of variance for phenological events, growth parameters, yield and yield related traits revealed a highly significant variation among the three rice genotypes except for the number of tillers/plant, grains/panicle and panicle length (Table 2). This was an indication that responses of the genotypes differ for the various traits tested.

3.2.1. Days to 50% heading

Days to 50% heading of the crop was highly significantly ($P < 0.01$) affected only by the main effect of the varieties while the main effect of timing of N-application and the interaction effect of the two factors did not affect this parameter (Table 2). Regardless of the N-timing treatments, Ediget and Gumara genotypes were almost uniform in attaining their days to 50% heading which was 100 and 102 days, respectively but the Nerica-4 genotype took 135 days to attain its 50% days to heading (Table 3).

3.2.2. Days to 90% physiological maturity

Days to 90% physiological maturity was highly significantly ($P < 0.01$) affected only by the main effect of varieties while the main effect of timing of N-application and the interaction effect of the two factors did not affect this parameter (Table 2).

Although N-timing differs, Ediget and Gumara genotypes were almost uniform in attaining their days to 90% physiological maturity which was 159 and 163 days, respectively. However, the Nerica-4 genotype took 183 days to attain its 90% days to physiological maturity (Table 3). According to the reports from the research centers where the varieties were released, the mean days to physiological maturity for Nerica-4, Gumara and Ediget is 110, 130 and 132, respectively (Table 3). The probable reason for this variation is due to the base temperature requirement of the crop. Base temperature is the minimum temperature whereby metabolic processes result in a net substance gain in aboveground biomass. It is an essential parameter for determining the beginning and the end of the growing season (Fageria *et al*., 1997).

If not all, most rice genotypes generally require an average temperature of above 22^0C during their growth period. Rice crop requires minimum night temperature of 13-15^0C, and if this minimum night temperatures extended over two to three nights during the panicle initiation and up to flowering periods, it results in reduced panicle branching and massive pollen and floret sterility (Heluf and Mulugeta, 2006). During the growth periods of the crop, the mean minimum temperature recorded was 10.7^0C, which is below the crop's minimum temperature requirement which in turn delayed days to heading and maturity.

3.2.3. Plant height (cm)

Analysis of variance showed that plant height was highly significantly ($P < 0.01$) affected only by the main effect of varieties while the main effect of timing of N-application and the interaction effect of the two factors did not affect this parameter (Table 2). The genotype Nerica-4 was shorter (47.92 cm) as compared to the two genotypes (Ediget and Gumara) in which the two are almost uniform in their mean plant heights (Table 3). Plant height is an important yield related parameter which is reported to be a genetic character that is influenced least by environmental factors such as nutrients and others (Hailu, 2010).

3.2.4. Number of panicles per plant

Number of panicles per plant was highly significantly ($P< 0.01$) influenced by the main effect of the varieties but not by the main effect of timing of N-application as well as by the interaction of the two factors (Table 2). Nerica-4 had the highest panicles per plant (7.917) followed by Gumara and Ediget had the lowest panicles per plant (Table 3). Number of panicle per plant is one of the yield attributes of rice that contributes to the grain yields and genotypes/cultivars having higher panicles per plant could have higher grain yield. Cultivars having higher number of grains per hectare may not necessarily have higher number of panicles per plant (Patra *et al*., 1992). In conformity with the findings of the present study, Thakur (2011) noted that panicle number of rice crop is the most important factor that causes variation in the grain yield of rice.

3.2.5. Number of filled and unfilled grains per panicle

Analysis of variance showed that number of filled and unfilled grains per panicle was highly significantly ($P < 0.01$) affected only by the main effect of genotypes while the main effect of timing of N-application and the interaction effect of the two factors did not affect these parameters (Table 3). According to the reports of the research center where the variety was released, Ediget was reported as if it is a cold resistant variety. The other varieties, Gumara and Nerica-4, were reported to be less resistant to low temperature. The low temperature during the rice crop growth stages affects the growth and yield of crop cultivars and hence crop cultivars differ in their base temperature requirement. The cool night minimum mean temperature (10.7^0C), which occurred during the flowering stage of the rice crop growth particularly from August to October, might have contributed to the reduction of the fertility of the panicles. Fageria *et al* (1997) reported that the prevalence of cool air temperature during the flowering stage of the crop increases sterility in rice crop by affecting pollination and fertilization of the panicles.

3.2.6. Grains yield (kg/ha)

The analysis of variance showed that grain yields of rice was highly significantly ($P < 0.01$) influenced by the main effect of the genotypes but not by the main effect of timing of N-application and their interaction (Table 2). The highest grain yields (822.7 kg/ha) were recorded from the genotype Ediget followed by Gumara which was 732 kg/ha. The lowest grain yields (342 kg/ha) was recorded from Nerica-4 genotype (Table 2). According to Adet agricultural research center, where the varieties were released, Ediget was reported to give 3200 kg/ha at farm condition but here it was 822.7 kg/ha only. The probable reason for the variation in grain yields might be the cool night minimum temperature during the growing periods of the crop.

3.2.7. Biomass yield (kg/ha)

The analysis of variance showed that biomass yields of rice was highly significantly ($P < 0.01$) influenced by the main effect of the genotypes but not by the main effect of timing of N-application and their interaction (Table 2). The highest biomass yields (2739 kg/ha) were recorded from the genotype Ediget followed by Gumara which was 2567 kg/ha. Like that of the grain yields, the lowest biomass yields (1767 kg/ha) was recorded from Nerica-4 genotype (Table 3).

Rice straw is an important resource for livestock feed and construction of houses in Ethiopia (Tilahun *et al*., 2012). Rice biomass yield has great implication for farmers where mixed crop-livestock farming is predominant as it is a means to increase availability of livestock feed.

Table 2: Mean square estimates for rice growth, yield and yield related parameters.

Source of variation	DF	DH	DP	PH	TP	PP	GP	NFP	NUGP	PL	TGW	GY	BY	HI
N	3	197.6	103.1	25.26	8.244	0.552	4.840	4.713	7.980	3.800	19.888*	3961	0.05	90.47*
V	2	4597.6**	1921.9**	260.86**	7.681	7.861**	0.443	28.813*	29.170*	1.404	40.929**	70479**	0.29**	310.83**
N * V	6	239.4	77.7	17.79	7.635	0.688	2.500	6.139	3.878	3.982	2.133	1866	0.02	21.57
Error	22	239.4	141.5	16.16	4.550	1.013	4.497	6.680	6.543	2.831	4.201	1710	0.03	19.61
CV		10.12	4.47	8.35	40.8	17.00	16.00	37.49	55.30	7.20	4.77	24.65	19.27	17.71

Where: DH = days to 50% heading ; DP = days to 90% physiological maturity ; PH = Plant height ; TP = Tillers per plant ; PP = Panicles per plant ; GP = Grains per panicle ; NFP = Number of filled grains per panicle ; NUGP = Number of unfilled grains per panicle ; PL = Panicle length ; TGW = Thousand grains weight ; GY = Grains yield ; BY = Biomass yield ; HI = Harvest index.

Table 3: Mean values to the crop phenological events, growth parameters and yield under different varietal treatments in Jimma (2012).

Treatments	DH	DP	PH	PP	NFP	NUGP	GY (kg/ha)	BY(kg/ha)
Variety								
Ediget	100.92a	159.92a	56.67a	6.333a	7.733a	3.90a	2739a	0.8217a
Gumara	102.50a	163.75a	55.08a	6.833a	8.700a	3.30a	2567a	0.7700a
Nerica-4	135.58b	183.50b	47.92b	7.917a	5.667b	6.25b	1767b	0.5300b
LSD (0.05)	11.10	7.33	4.31	2.05	2.68	2.41	45.38	0.13

Where, DH = days to 50% heading; DP = days to 90% physiological maturity; PH = Plant heights; PP = Panicles per plant; NFP = Number of filled grains per panicle; NUGP = Number of unfilled grains per panicle; GY = Grains yield and BY = Biomass yield. Means sharing the same superscript letter in the columns do not differ significantly at P = 0.05 according to the LSD test.

3.2.8. Thousand grains weight (gm)

The analysis of variance showed that the main effects of varieties and timing of N-fertilizer application highly significantly (P < 0.01) influenced thousand grains weight. However, the interaction of the two factors did not affect this parameter (Table 2). Ediget had the highest thousand grains weight (26.383 gm) and Nerica-4 had the lowest value (22.808 gm) (Table 4). Split application of nitrogen fertilizer in which 25% of the fertilizer is applied at sowing, 25% at active tillering stage and the remaining 50% at panicle initiation gave the highest thousand grains weight (27.033 gm) whereas the lowest value (23.956 gm) was recorded from the fourth treatment in which the application was 1/3rd at sowing, 1/3rd at active tillering stage and the other 1/3rd at panicle initiation. N_4 was almost uniform with the control treatment (Table 4). Thousand grains weight is an important yield determining component and reported to be a genetic character that is influenced least by environmental factors (Hailu, 2010).

Due to the mobile nature of nitrogenous fertilizers and their leaching problems, large doses at the seedling stage of the crop growth is not advisable as the crop will not have sufficient capacity to take up large amounts of the nutrient due to its scanty roots, and hence it is advisable to apply the major fraction of the fertilizers during its active tillering and its panicle initiation stage (Thakur, 2011).

Due to the mobile nature of nitrogenous fertilizers and their leaching problems, large doses at the seedling stage of the crop growth is not advisable as the crop will not have sufficient capacity to take up large amounts of the nutrient due to its scanty roots, and hence it is advisable to apply half of the fertilizers during its panicle initiation stage.

Table 4: Mean thousand grains weight of rice as affected by main effect of variety and timing of nitrogen fertilizer application in Jimma (2012).

Treatments	Thousand Grains Weight (gm)
Varieties	
Ediget	26.383a
Gumara	25.400a
Nerica-4	22.808b
LSD (0.05)	1.15
N-timing	
N_1	23.956a
N_2	24.622a
N_3	27.033b
N_4	23.844b
LSD (0.05)	1.72

Where, N_1= 50% at sowing and 50% at active tillering stage, N_2= 25% at sowing + 50% at active tillering stage and 25% at panicle initiation, N_3 =25% at sowing + 25% at active tillering stage and 50% at panicle initiation, N_4 =33% at sowing + 33% at active tillering stage and 33% at panicle initiation. Means sharing the same superscript letter in the columns do not differ significantly at P = 0.05 according to the LSD test.

3.2.9. Harvest index (%)

Harvest index was computed as the ratio of grain yield to the total above ground dry biomass yield. Harvest index responded significantly to the main effects of varieties and N-application timings but not for their interaction (Table 2). Ediget was superior in its harvest index (30%) followed by Gumara (28.7%) and Nerica-4 was the least (20.6%) (Table 5). Split application of nitrogen fertilizer in which 25% of the fertilizer applied at sowing, 25% at active tillering stage and the remaining 50% at panicle initiation produced the highest harvest index value

International Journal of Agriculture Innovations and Research
Volume 4, Issue 1, ISSN (Online) 2319-1473

(25.85%) whereas the lowest value (17.25%) was recorded from the fourth treatment (Table 5). HI is a useful index in evaluating treatment effects in partitioning photoassimilates into grain within a given environment (Taddesse, 2009).

Table 5: Mean harvest index of rice as affected by main effect of variety and timing of nitrogen fertilizer application in Jimma (2012).

Treatments	**Harvest index (%)**
Varieties	
Ediget	30.042a
Gumara	28.660a
Nerica-4	20.620b
LSD (0.05)	4.54
N-timing	
N1	23.45a
N2	24.75a
N3	25.85a
N4	17.25b
LSD (0.05)	1.60

Where, N_1= 50% at sowing and 50% at active tillering stage, N_2= 25% at sowing + 50% at active tillering stage and 25% at panicle initiation, N_3 =25% at sowing + 25% at active tillering stage and 50% at panicle initiation, N_4 =33% at sowing + 33% at active tillering stage and 33% at panicle initiation. Means sharing the same superscript letter in the columns do not differ significantly at P = 0.05 according to the LSD test.

Fageria (2007) reported that HI changes with cultivar and with the environmental conditions during the reproductive growth stage. HI is an important plant trait for improving grain yield in cereals (Fageria, 2007). Furthermore, higher nitrogen use efficiency has also been observed in rice cultivars with high harvest index (Fageria, 2005). The HI values of modern crop cultivars are commonly higher than old traditional cultivars for major field crops (Balasubramanian, 2002). Kebebew *et al.* (2002) reported that upland rice yield can be significantly improved with developing genotypes of higher grain harvest index.

3.3. Correlation analysis

The correlation analysis indicated that most of the phenological events, growth parameters, yield and yield related traits had either positive or negative relation with each other (Table 6). The analysis regarding the yield and other major yield related traits indicated that grain yield was positively correlated (P<0.01) with plant heights (r=0.68**), number of filled grains per panicle (r=0.52**) and thousand grains weight (r=0.61**) and negatively correlated with most of the traits. Days to 50% heading was observed to be positively and significantly (r= 0.70**) correlated with days to 90% physiological maturity. Plant heights showed positive correlation (r=0.69**) with biomass yield but showed negative correlation (r=-0.58**) with number of panicles per plant. Thousand grains weight is also showed positive and significant correlation (r= 0.58**) with plant heights however it was observed to be negatively correlated with days to 50% heading and 90% physiological maturity and with most growth parameters.

Table 6: Simple correlation coefficients for phenology, yield and yield related traits of rice

Parameters	**DH**	**DP**	**PH**	**TP**	**PP**	**GP**	**NFP**	**NUGP**	**PL**	**TGW**	**GY**	**BY**	**HI**
DH	-												
DP	0.70**	-											
PH	-0.506**	-0.817**	-										
TP	-0.048	-0.246*	0.319*	-									
PP	0.326*	0.508**	-0.584**	-0.262*	-								
GP	0.383*	0.076	-0.170	0.382*	-0.076	-							
NFP	-0.332*	-0.354*	0.152	0.056	-0.124	0.366*	-						
NUGP	0.605**	0.413*	-0.274*	0.212*	0.073	0.331*	-0.757**	-					
PL	0.163	0.095	-0.053	0.490**	0.282*	0.192	-0.078	0.215*	-				
TGW	-0.66**	-0.656**	0.578**	-0.320*	-0.433**	-0.334*	0.344*	-0.584**	-0.618**	-			
GY	-0.691**	-0.767**	0.679**	0.210*	-0.397*	-0.008**	0.515**	-0.529*	-0.037	0.61*	-		
BY	-0.56**	-0.673**	0.690**	0.286*	-0.376*	-0.052	0.182	-0.221*	0.165	0.36*	0.75**	-	
HI	-0.528**	-0.613**	0.402*	0.144	-0.309	0.081	0.596**	-0.547**	-0.188	0.56**	0.77**	0.20	-

*, **: Significant at 0.05 and 0.01 probability levels, respectively.

DH = days to 50% heading; DP = days to 90% physiological maturity; PH = Plant height; TP = Tillers per plant; PP = Panicles per plant; GP = Grains per panicle; NFP = Number of filled grains per panicle; NUGP = Number of unfilled grains per panicle; PL = Panicle length; TGW = Thousand grains weight; GY = Grains yield; BY = Biomass yield; HI = Harvest index.

IV. Summary and Conclusion

Managing N application to rice is an essential activity to reduce N losses and to improve N use efficiency which in turn improves rice grain yields. An attempt was made to synchronize N supply with rice crop demands to achieve adequate grain yield forming components and, consequently, higher grain yields.

Three rice genotypes in different nitrogen timings were evaluated during the 2014 main cropping season to examine the fertilizer application practice to maximize use efficiency of N and hence to increase yield of rice in Jimma area. Accordingly, the results of analysis of variance revealed significant differences among the rice genotypes for grain yields, biomass yield and other traits.

The N-timing treatments did not influence almost all of the parameters studied except thousand grains weight and harvest index. Although statistically non-significant, number of filled grains per panicle was in increasing trend and it is the most important yield-contributing trait which can be manipulated significantly with the N fertilization application at an appropriate growth stage during the crop growth cycle. Nitrogen applied in the reproductive growth stage (panicle initiation to booting and flowering) did not improve the rice grain yield as compared to N applied during early growth stages (at sowing and tillering stages). Both grain and biomass yield production exhibited a greater response to mid-season application of N as compared to the early and late-season application.

This implies that, much nitrogen applied late in the season during the reproductive growth stages might be absorbed by the crop, but it is not utilized in grain yield improvement. On the other hand, N applied during the early growth stage (during sowing) of the crop might have been subjected to losses due to leaching and denitrification as well as due to the scanty roots of the crop which has less ability for nutrient absorption. Likewise, N applied around mid-season of the crop (the major portion of N during active tillering stage of the crop) increased grain yields.

In general, plots treated with N-fertilizer splitted three times (1/4th at sowing + ½ at active tillering stage and the remaining 1/4th at panicle initiation produced the highest grain and biomass yields along with Ediget genotype though statistically non-significant. Therefore, Ediget genotype can be recommended for the farmers in the study area to maximize grain yield.

This study gave an insight for further study and consideration of the dissemination of rice genotypes to different agro-ecologies of an area since the rice genotypes were found to have different responses. Hence, further study on the genotype by environment interaction effects of upland rice genotypes on multi-locations for a number of years would generate sufficient information that enables appropriate recommendations to be made.

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