Genetic variability in nitrogen use efficiency of upland rice varieties in West Amhara, Ethiopia

Taddesse Lakew[1], Ketema Belete[2] and Wondimu Bayu[3]

[1]Adet Agricultural Research center, P.O.Box (08), Bahir Dar, Ethiopia; [2]Haramaya University, P.O.Box 138, Dire Dawa, Ethiopia; [3]ICARDA-Coordinator, P.O.Box 527, Bahir Dar, Ethiopia

[*]E-mail: taddesse.lakew@yahoo.com

Abstract

Use of nitrogen efficient genotypes is an important complementary strategy in improving rice yield and reducing cost of production in subsistence farming. A field experiment was conducted at Woreta, Fogera district of South Gondar Zone, during the 2009 main cropping season. The objectives were to investigate genetic variability in nitrogen use efficiency of upland rice genotypes, to identify genotypes with best nitrogen use efficiency and to assess the nature of association between nitrogen use efficiency traits and yield and yield related traits. Twelve upland rice genotypes (6 released and 6 candidate) with two nitrogen levels (0 and 64 kg N ha^{-1}) were evaluated in a factorial randomized complete block design with three replications. Analysis of variance revealed significant differences among genotypes for yield and yield related traits and nitrogen use efficiency and its component traits. Differences were significant between nitrogen levels for the number of filled spikletes panicle^{-1}, grain yield, and biomass yield and nitrogen use efficiency component traits. Genotype×nitrogen interaction effect was not significant for all traits. The highest grain yield of 5437.7 kg ha^{-1} was obtained from NERICA-3 followed by NERICA-4 (5252.9kg ha^{-1}). Nitrogen uptake, nitrogen utilization and nitrogen use efficiency varied from 21.87 to 48.43%, 21.46 to 53.4 kg kg^{-1} N and 8.71 to 31.87 kg kg^{-1} N, respectively. Grain yield, harvest index, grain nitrogen yield, nitrogen harvest index, nitrogen uptake efficiency, nitrogen utilization efficiency and nitrogen use efficiency had high genotypic and phenotypic coefficient of variation and high broad sense heritability estimates. Grain yield showed significant and positive correlation with grain nitrogen yield, and nitrogen harvest index. Grain nitrogen concentration had significant and positive correlation with nitrogen uptake efficiency and nitrogen use efficiency. Nitrogen efficient genotypes (Superica-1, NERICA-4 and NERICA-3) could be used in production and also in breeding program to produce varieties of better nitrogen use efficiency.

Key words: Efficiency, nitrogen, rice, uptake, utilization.

Introduction

Rice, *Oryza sativa* (2n = 24), is the second most important cereal crop and staple food for more than one third of the world's population (International year of rice, 2004). It has two cultivated and more than 30 wild species with a broad geographic distribution (Watanabe, 1997). The cultivated species are *Oryza sativa L.,* which is Asian origin and *Oryza glaberrima Steud,* an African origin. Rice production in the world increasingly focuses on optimizing grain yield, reducing production costs, and minimizing pollution risks to the environment (Koutroubas and Ntanos, 2003). One of the inputs limiting rice production is nitrogen (N). However, 50–70% of the applied nitrogen (N) is not used by crop plants leading low nitrogen use efficiency (NUE) of 32% (Tilman *et al*., 2002). Nitrogen use efficiency is the ability of the plant to produce a unit of grain per kg of nitrogen applied to the soil (kg grain kg^{-1} N). It is determined by the ability of the plant to extract soil nitrogen (Nitrogen uptake efficiency, NUPE %), and by the ability to convert the absorbed nitrogen into grain yield (Nitrogen utilization efficiency, NUTE, kg grain kg^{-1} N) (Molle *et al*., 1982). The need for developing and identifying superior N efficient genotypes is evident from the low recovery of N fertilizer, associated economic and environmental concerns. Moll *et al*. (1982) recommended selecting cultivars with high NUPE and NUTE. Samone *et al*. (2006) also indicated that NUE should be considered both when developing cultivars and when making fertilizer N recommendations.

Selection in plant breeding techniques, in Ethiopia, helped to developing rice varieties that are high yielding and diseases resistant. However, genetic selection to improve rice N-use efficiency has not yet been done. Hence, there is no information on NUE variability and its relation with yield and yield related traits among rice cultivars. Moreover, in Ethiopian subsistence farming, fertilizer inputs are very expensive and mostly not affordable. Therefore, to minimize cost of production for resource poor farmers and environmental pollution and for developing sustainable rice production evaluation of rice genotypes for N use efficiency is necessary. The study aimed at investigating genetic variability in N use efficiency among upland rice genotypes, identifying genotypes with best N use efficiency and also assessing nature of association among N use efficiency and yield and yield related traits.

Methodology

The study area

The experiment was conducted at Woreta (13^{O} 19' N and 37^{O} 03'E) located at an altitude of 1815 m above sea level in Fogera district of South Gondar Zone in 2009. Woreta receives an average annual rainfall of 1284.94 mm and the mean maximum and minimum temperatures during the main cropping season are 26.7 ^{O}C and 12.2 ^{O}C, respectively. The experimental site is characterized by a pH of 6.49, organic carbon of 3.4%, total N of 0.18%, available P of 21.2 mg kg^{-1} , CEC of 56.5 cmol(+) kg^{-1} soil and exchangeable K of 0.93 cmol(+) kg^{-1} soil.

Experimental materials and design

Twelve upland rice genotypes (six released varieties and six in pipelines) were used for this study. Genotypes were studied under two N fertilizer levels (0 and 64 kg N ha^{-1}) using a factorial randomized complete block design with three replications. Each plot had 6 rows of 20 cm apart and the gross plot area was 3.6 m^2 (1.2 m ×3 m) with harvestable plot size of 2.4 m^2 (0.8 m ×3 m). The space between blocks and plots was 1.5 m and 50 cm, respectively. The seed was drilled at the rate of 80 kg ha^{-1}. Nitrogen fertilizer, in the form of urea, was applied in three splits at planting, tillering and at panicle initiation 1/3 each. Phosphorus fertilizer in the form of TSP was uniformly applied to plots at the rate of 46 kg P_2O_5 ha^{-1} all at planting.

Data collection

Data on days to heading, days to flowering, days to maturity, plant height, panicle length, number of tillers per meter row, number of spikelets per panicle, number of filled spikelets per panicle, grain yield, thousand–kernel weight, biomass yield, harvest index, tissue N content, N harvest index and grain protein content were collected. Grain N (GNC) and straw N concentrations (SNC) were determined by Kjeldahl method: percentage of N was estimated using the formula: $\%N = \frac{(a-b) \times M \times 14}{SM} \times 100$; Where, H consumed in the titration by the blank sample, M = molality of HCl, 14 = molecular weight of N, SM = sample mass. Then, grain protein content (GPC) in percent, grain N yield (GNY) in kg ha^{-1}, straw N yield (SNY) in kg ha^{-1}, biomass N yield (BNY) in kg ha^{-1} and N harvest index (NHI) in percent was calculated as follows: GPC = GNC ×5.13, $\text{GNY} = \frac{(\text{GNC} \times \text{GY})}{100}$, $\text{SNY} = \frac{\text{SNC} \times (\text{BY} - \text{GY})}{100}$, BNY= (GNY+SNY), $\text{NHI}(\%) = \left(\frac{\text{GNY}}{\text{BNY}} \times 100\right)$; Where, GNC= grain N concentration (%), GY = grain yield (kg ha^{-1}), SNC = straw N concentration (%), BY = biomass yield (kg ha^{-1}). Then, applied N uptake efficiency (ANUPE; %), applied N utilization Efficiency (ANUTE; kg kg^{-1}N) and applied N use efficiency (ANUE; kg kg^{-1}N) were calculated as follows: $\text{ANUPE} = \left(\frac{\text{BNYf} - \text{BNY0}}{\text{Nf}}\right) \times 100$, $\text{ANUTE} = \left(\frac{\text{GYf} - \text{GY0}}{\text{BNYf} - \text{BNY0}}\right)$, $\text{ANUE} = \left(\frac{\text{GYf} - \text{GY0}}{\text{Nf}}\right)$ Where, BNYf = biomass N yield in N–fertilized plot (kg ha^{-1}), BNY0 = biomass N yield in non N-fertilized plot (kg ha^{-1}), Nf = N fertilizer applied (kg ha^{-1}), GYf = grain yield in N-fertilized plot (kg ha^{-1}), GY0 = grain yield in non-N fertilized plot (kg ha^{-1})

Statistical analysis

Analysis of variance (ANOVA) was performed using SAS (PROC GLM) (SAS, 2000). Mean separation was done using LSD comparison test. Variance component analysis was used to estimate coefficient of variability and broad sense heritability. Association of traits between N use efficiency traits and grain yield and yield related traits were determined following the correlation coefficient analysis using SAS software.

Variances, coefficient of variability and broad-sense heritability

The components of variance were determined following SAS system of analysis. Then, phenotypic variance (σ^2_{ph}) was obtained as: $\sigma^2_{ph} = \sigma_g^2 + \sigma^2_{gn}/n + \sigma^2_e/nr$: Where, σ_g^2 = genotypic variance, σ_{gn}^2 = G × N interaction component of variance, σ_e^2 = error variance, n = number of nitrogen levels, r = number of replications. Phenotypic (PCV) and genotypic (GCV) coefficients of variations were computed according to the method described by Hansen *et al.* (1956): $\text{PCV} = \frac{\sqrt{\text{phenotypic variance}}}{\text{population mean for the trait}} \times 100$, $\text{GCV} = \frac{\sqrt{\text{Genotypic variance}}}{\text{population mean for the trait}} \times 100$.

Heritability (H) in broad sense was estimated from the total genetic variance using the formula given by Falconer and Mackay (1996): $H(\%) = \frac{\sigma_g^2}{\sigma_{ph}^2} \times 100$; where, $\sigma_g^2 = genotypic\ variance$ and $\sigma_{ph}^2 = phenotypic\ variance$.

Results and discussion

Yield and yield related traits

Analysis of variance revealed significant differences among the genotypes for most of the traits considered ($p<0.05$) indicating presence of genetic variation among genotypes and possibility of manipulating these variations for improvement. This is in accordance with the previous reports on rice by Fageria and Barbosa Filho (2001), Sokat (2006) and Singh *et al.* (1998). The genotype by nitrogen (G×N) interaction component was not significant for all traits implying the performance of genotypes were independent of the levels of N fertilizer.

Grain yield of genotypes ranged from 2852.9 to 5437.7 kg ha^{-1} (Table 1). The highest grain yield was recorded from NERICA-3 followed by NERICA-4. These genotypes also have the highest number of filled spikelets per panicle (Table 1). This indicates that number of filled spikelets per panicle contributes for high grain yield performance. Similarly, Fageria and Baligar (1999) reported that filled spikelets per panicle and total grains per panicle were most important yield components in determining grain yield in rice genotypes, respectively. Harvest index of the genotypes varied from 15.36 to 39.64%. In the present study, harvest index seems to be important yield component as high yielding genotypes (NERICA-3, NERICA-4, IRGA370-38-1-1F-B1-1 and WAB450-11-1-1-P31-HB) had the highest harvest index (Table 1).

Table 1. Yield and yield related traits of 12 upland rice genotypes averaged across two N levels at Woreta in 2009.

Genotypes	DTH (days)	DTM (days)	PH (cm)	PL (cm)	NTMRL (No)	NETMRL (No)	NSPP (No)	NFSPP (No)	GY (kg ha^{-1})	TKW (g)	BY (kg ha^{-1})	HI (%)
NERICA-3	102.3	148.0	79.3	19.1	441.5	421.5	110.2	103.5	5437.7	25.0	16451	37.5
NERICA-4	102.7	149.8	84.5	19.1	511.3	486.3	115.3	107.2	5252.9	24.5	14224	39.6
Superica-1	107.7	160.0	91.4	18.7	409.3	353.3	101.7	78.8	4004	25.6	14104	28.6
Andassa (AD012)	118.2	170.7	99.1	20.1	389.3	328.0	100.0	73.1	3535.9	26.1	16264	20.8
Tana (AD048)	113.8	168.0	96.7	19.4	414.0	373.3	103.0	81.2	3104.3	26.2	17350	15.4
Getachew (AD01)	113.8	172.7	90.4	19.8	534.0	446.7	97.5	75.4	2852.9	24.8	12770	23.3
CNAX3031-15-2-1-1	103.0	161.0	79.6	18.1	454.7	420.7	101.7	80.1	3694.1	25.8	13606	27.7
IRGA370-38-1-1F-B1-1	101.0	154.3	75.4	17.9	426.7	371.3	91.3	72.1	5058	27.7	14938	37.8
WAB502-8-5-1	108.8	171.2	95.4	18.7	401.3	346.0	105.7	82.0	3026.9	29.5	12247	25.2
WAB450-11-1-1-P31-HB	105.5	166.0	95.2	20.2	407.3	374.7	118.0	88.5	5008.9	25.2	16323	31.1
WAB95-B-B-40-HB	106.7	165.3	97.8	19.2	430.0	383.3	100.0	76.5	4206.5	27.6	19330	24.0
WAB368-B-HI-HB	107.7	160.3	72.8	17.7	363.3	315.3	94.9	76.0	3053.8	31	12337	23.2
Mean	107.7	162.3	88.2	19.0	432.0	385.0	103.3	83.0	4019.7	26.6	14995.2	28.0
CV (%)	2.08	3.79	7.66	4.72	16.96	18.26	9.03	11.98	7.28	19.01	25.65	26.46
LSD (5%)	2.60	7.15	7.84	1.04	85.10	81.72	11.89	11.53	888.18	2.25	4470.9	8.57

DTH = Days to heading, DTM = Days to maturity, PH = Plant height, PL = Panicle length, NTMRL = Number of tillers per meter row length, NETMRL = Number of effective tillers per meter row length, NSPP = Number of spikeletes per panicle, NFSPP = Number of filled spikelets per panicle, GY = Grain yield, TKW = Thousand kernel weight, BY = Biomass yield and HI = Harvest index.

Nitrogen use efficiency and its component traits

Genotypic effects were significantly different for all N use efficiency and its component traits (<0.05) (Table 2). In the current study, wide ranges of mean values were recorded for grain N yield, straw N yield, biomass N yield and N harvest index (Table 2). Similar results were reported by Singh *et al.* (1998), Fageria *et al.* (2010) and Woldeyesus *et al*. (2004).

Higher and significant grain N concentration was obtained from NERICA-3, NERICA-4, Andassa, Tana and Getachew (Table 2). Grain protein content was the highest for NERICA-4 and lowest for CNAX3031-15-2-1-1. Genotypes showed significant differences in N harvest index with the overall mean of 49.53%. N harvest index of NERICA-3, NERICA-4, Superica-1, IRGA370-38-1-1F-B1-1 and WAB450-11-1-1-P31-HB were higher than the overall mean (Table 2). Rattunde and Frey (1986) reported that genetic variability for N harvest index exists within the small seeded genotypes and high N harvest index is associated with efficient utilization of N.

In this study, wide ranges of means were recorded for NUPE (21.87 to 48.43%), NUTE (21.46 to 53.40 kg kg^{-1} N) and NUE (8.71 to 31.87 kg kg^{-1}N) (Table 2). NERICA-3, NERICA-4, Andassa, Superica-1, WAB450-11-1-1-P31-HB and WAB95-B-B-40-HB had higher NUPE than the overall mean (Table 2). Of the tested genotypes, the highest nitrogen use efficiency was recorded for Superica-1 followed by Andassa, while NERICA-3 and NERICA-4 had relatively higher nitrogen use efficiency (Table 2).

Table 2. Nitrogen use efficiency and its component traits of 12 upland rice genotypes averaged across two N levels at Woreta in 2009.

Genotype	GNC (%)	GPC (%)	GNY (kg ha^{-1})	SNC (%)	SNY (kg ha^{-1})	BNY (kg ha^{-1})	NHI (%)	ANUPE (%)	ANUTE (kg kg^{-1}N)	ANUE (kg kg^{-1}N)
NERICA-3	1.77	9.06	96.85	0.59	65.17	162.01	62.33	34.87	49.92	22.89
NERICA-4	1.88	9.66	99.79	0.54	47.16	146.95	67.17	48.43	27.63	24.24
Superica-1	1.66	8.09	65.08	0.61	61.38	126.6	52.34	43.42	40.49	31.87
Andassa (AD012)	1.86	9.36	65.73	0.65	82.71	148.45	42.98	40.44	33.37	29.46
Tana (AD048)	1.81	9.27	56.01	0.67	90.7	146.71	36.27	31.25	23.93	17.25
Getachew (AD01)	1.78	9.11	51.36	0.66	65.34	116.7	44.15	30.16	21.46	13.98
CNAX3031-15-2-1-1	1.51	7.75	55.94	0.61	60.62	116.56	48.22	25.78	36.21	18.67
IRGA370-38-1-1F-B1-1	1.59	8.09	80.61	0.73	69.15	149.75	54.95	25.43	32.33	8.71
WAB502-8-5-1	1.64	8.39	49.85	0.59	54.26	104.1	47.68	29.53	22.79	11.95
WAB450-11-1-1-P31-HB	1.57	8.04	78.54	0.62	69.76	148.3	51.99	34.40	35.6	15.39
WAB95-B-B-40-HB	1.62	8.06	68.08	0.68	98.09	166.21	44.16	37.50	27.53	17.46
WAB368-B-HI-HB	1.51	7.78	46.1	0.69	66.5	112.6	42.08	21.87	53.4	18.97
Mean	1.68	8.55	67.83	0.64	69.23	137.08	49.53	33.61	33.72	19.24
CV (%)	10.84	11.43	19.28	18.89	32.58	21.18	17.75	27.13	30.15	28.82
LSD (5%)	0.21	1.36	15.2	0.14	26.22	33.74	10.22	18	17.21	9.39

GNC= grain N concentration, GPC= grain protein content, SNC= straw N concentration, GNY=grain N yield, SNY= straw N yield, BNY= biomass N yield, NHI= N harvest index, ANUPE= applied N uptake efficiency, ANUTE= applied N utilization efficiency, and ANUE= applied N use efficiency.

Genotypic and phenotypic coefficient of variations

Genotypic and phenotypic coefficients of variation are used to measure the variability that exists in a given population (Burton and Devane, 1953). As indicated in Table 3, genotypic coefficient of variation (GCV) was less than its corresponding estimates of phenotypic coefficient of variation (PCV) for all traits indicating significant role of environment in the expression of these traits. The difference between PCV and GCV was wide for the three N use efficiency traits, biomass N yield and number of filled spikelets per panicle. For the other traits, however, both the environment and genetic component are nearly equally important for the depiction of phenotypes (Table 3). Khan *et al*. (2009) reported on rice genotypes that PCV values were higher than GCV values for all important traits considered.

Heritability

In the present study, broad-sense heritability estimates for the 22 traits ranged from 40.37% to 99.42% (Table 3). Dabholkar (1992) generally classified heritability estimates as low (5-10%), medium (10-30%) and high (30-60). Based on this classification, almost all traits under this study exhibited high to very high heritability estimates (Table 3). Similar result was reported by Woldeyesus *et al*. (2004) on barely genotypes and by Alemayehu *et al*. (2006) on tef genotypes that broad-sense heritability estimates were higher for grain yield, grain N yield, biomass N yield and nitrogen harvest index and for N use efficiency traits.

Correlation

Improvement for a trait of interest can be achieved by selection through other traits that are more heritable and easy to select. It, therefore, requires understanding the interrelationship of the other traits among themselves and with traits of interest. In this study, significant and positive correlations were observed for grain N concentration with days to heading (r = 0.36), days to flowering (r = 0.33) and for grain protein content with days to heading and days to flowering (r = 0.340 (Table 4). On the other hand, grain N yield had significant and negative correlation with days to heading (r = -0.48) and days to maturity (r = -0.67). Grain N yield showed significant and positive correlation with grain yield (r = 0.93), biomass yield (r = 0.44) and with harvest index (r = 0.58) (Table 4). In agreement to this, Samonte *et al*. (2006) reported significant and positive correlation between grain N yield and grain yield (r = 0.49). The present study revealed that correlations between grain yield and N use efficiency traits were positive and very weak (Tables 4). However, positive and very weak correlation between grain yield and N use efficiency traits may not prevent concurrent improvement of these traits.

Table 3. Estimate of mean, range, variance components, coefficients of variation and heritability in the broad sense of various trait in 12 upland rice genotypes grown under two N levels at Woreta in 2009.

Trait	Mean± SE	Range	σ_g^2	σ^2_{ph}	GCV	PCV	H
DTH	107.67 ±1.29	101.67-118.16	27.3800	28.6904	4.86	4.98	95.43
DTM	162.28 ±3.55	148-172.67	63.4100	67.7880	4.9	5.07	93.54
PH	88.16 ±3.89	72.82-99.05	78.9100	87.6950	10.1	10.6	89.98
PL	18.98 ±0.52	17.25-20.15	0.4900	0.6833	3.7	4.4	71.71
NTMRL	431.9 ±42.28	363.33-534	1705.7000	2386.9583	9.6	11.3	71.46
NETMRL	385.04±40.60	315.33-446.67	1944.0000	2521.2733	11.5	13	77.10
NSPP	103.25±5.91	91.32-118.03	42.5000	62.8033	6.3	7.7	67.67
NFSPP	82.85 ±5.73	71.33-88.53	109.6500	130.3050	1.26	13.8	84.15
TKW	26.58 ±1.12	24.53-30.87	3.2600	3.8611	6.79	7.39	84.43
GY	4019.66 ±441.3	2852.9-5437.7	8666033.8	8716464.95	73.24	73.44	99.42
BY	14995.2± 2221.1	12247-19330	2412843.2	4792916.17	10.36	14.59	50.34
HI	27.97 ±4.26	15.36-39.64	50.5500	55.4013	25.51	26.71	91.24
GNC	1.68± 0.10	1.51-1.88	0.0124	0.0172	6.63	7.8	72.16
GPC	8.55 ±0.57	7.73-9.66	0.3892	0.4772	7.29	8.08	81.56
SNC	0.64 ±0.07	0.54-0.73	0.0011	0.0027	5.18	8.07	41.25
GNY	67.83 ±7.55	46.1-99.79	296.6370	318.3098	25.39	26.3	93.19
SNY	69.23± 13.03	47.16-98.09	155.4900	214.7335	18.01	21.17	72.41
BNY	137.01±16.76	104.1-166.21	355.8700	428.8265	3.76	15.11	82.99
NHI	49.53 ± 5.08	36.26-67.16	69.0208	77.7868	16.77	17.81	88.73
ANUPE	60.97±13.50	30.76-88.32	269.9100	543.3900	26.95	38.23	49.67
ANUTE	33.72±8.30	21.46-53.4	69.9500	173.2900	24.80	39.04	40.37
ANUE	19.14±4.53	8.71-3.87	36.6700	67.4100	31.47	42.62	54.40

SE = standard error of the mean, σ_g^2= genotypic variance, σ^2_{ph}= phenotypic variance, GCV= genotypic coefficient of variation, PCV = Phenotypic coefficient of variation, H = Heritability in the broad sense, DTH = Days to heading, DTM = Days to maturity, PH = Plant height, PL = Panicle length, NTMRL = Number of tillers per meter row length, NETMRL = Number of effective tillers per meter row length, NSPP = Number of spikeletes per panicle, NFSPP = Number of field spikeletes per panicle, TKW = 1000 kernel weight, GY = Grain yield, BY = Biomass yield, HI = Harvest index, GNC = Grain nitrogen concentration, GPC = Grain protein content, SNC = Straw nitrogen concentration, GNY = Grain nitrogen yield, SNY = Straw nitrogen yield, BNY = Biomass nitrogen yield, NHI = Nitrogen harvest index, ANUPE = Applied uptake efficiency ANUTE = Applied utilization efficiency, ANUE = Applied nitrogen use efficiency

Table 4. Phenotypic correlation coefficients between yield and yield related and nitrogen use efficiency and its component traits in twelve upland rice genotypes grown under two nitrogen levels at Woreta during 2009 main cropping season.

Trait	DTH	DTM	PH	PL	NTMRL	NETMRL	GY	BY	HI
GNC	0.360*	0.005	0.08	0.09	0.05	-0.005	-0.05	0.17	-0.17
SNC	0.14	0.111	0.01	0.14	0.102	0.09	-0.19	0.11	-0.23
GP	0.34*	0.02	0.06	0.09	0.12	0.08	-0.05	0.15	-0.18
SNY	0.29	0.22	0.48**	0.46**	-0.06	-0.05	0.005	0.81***	-0.61***
GNY	-0.48**	-0.670***	-0.23	-0.19	-0.03	0.03	0.93***	0.44**	0.58**
BNY	-0.13	-0.33	0.04	0.07	0.003	0.05	0.60***	0.62***	0.09
NHI	-0.61***	-0.680***	-0.52**	-0.49**	0.05	0.09	0.65***	-0.3	0.93***
ANUPE	0.36	0.09	0.24	0.09	0.21	0.16	0.09	-0.04	-0.05
ANUTE	-0.20	-0.23	-0.39*	0.22	-0.42	-0.34	0.03	0.07	-0.05
ANUE	0.20	-0.12	-0.07	-0.14	-0.21	-0.18	0.06	0.03	-0.04

*, **, and *** significant at 0.05, 0.01 and 0.001 probability levels, respectively. DTH = Days to heading, DTM = Days to maturity, PH = Plant height, PL = Panicle length, NTMRL = Number of tillers per meter row length, NETMRL = Number of effective tillers per meter row length, GY = Grain yield, BY = Biomass yield, HI = Harvest index, TKW = 1000 kernel weight, GNC = Grain nitrogen concentration, SNC = Straw nitrogen concentration, GPC = Grain protein content, SNY = Straw nitrogen yield, GNY = Grain nitrogen yield, BNY = Biomass nitrogen yield, ANUPE = Applied uptake efficiency, ANUTE = Applied utilization efficiency, ANUE = Applied nitrogen use efficiency, NHI = Nitrogen harvest index.

Conclusion and recommendation

Highly significant variations among genotypes for yield and yield related traits and for N uses efficiency traits were observed in the current study. NERICA-3 and NERICA-4 were genotypes with high mean values for grain yield, number of filled spikelets per panicle, harvest index, grain N concentration and N harvest index. Nitrogen use efficiency was highest for Superica-1, Andassa, NERICA-4, and NERICA-3. Phenotypic coefficient of variation (PCV) and genotypic coefficients of variation (GCV) values were very high for grain yield, harvest index, N use efficiency, utilization efficiency, uptake efficiency and N harvest index. Heritability estimates were very high for grain yield, days to heading, days to maturity, harvest index and grain N yield. Grain yield had significant and positive correlations with grain N yield and N harvest index.

The information generated from this study has significant insinuation in nitrogen use efficiency variability. However, the findings of this study were based on one location and one cropping season data on limited number of genotypes. Therefore, further investigations using more diverse locations and more number of genotypes is essential to generate reliable and conclusive information on genetic variability in nitrogen use efficiency of upland rice genotypes and identify nitrogen efficient genotypes for use in the breeding program or for commercial production.

References

Alemayehu, B., R. Gretzmacher and Johann Vollman. 2006. Genetic variation in nitrogen-use efficiency of tef. *Journal of Plant Nutrition and Soil Science*, 169:704-710.

Burton, G.W. and E. H. Devane. 1953. Estimating heritability in tall Fescue (*Festuca arundinacea*) from replicated clonal materials. *Agronomy Journal*, 45:487-488.

Dabholkar, A. R. 1992. Elements of biometrical genetics. Concept Publishing Company, New Delhi, India. 431p.

Fageria, N. K. and V. C. Baligar. 1999. Yield and yield components of lowland rice genotypes as influenced by timing of nitrogen fertilization. *Journal of Plant Nutrition,* 22:23-32.

Fageria, N. K., and M. P. Barbosa Filho. 2001. Nitrogen use efficiency in lowland rice genotypes. *Community of Soil Science, Plant Analysis*, 32(13&14): 2089-2089.

Fageria, N.G., O.P.D.Morais and A.B. D Santos. 2010. Nitrogen Use efficiency in Upland Rice Genotypys. *Journal of plant Nutrition*. 33: 1696-1711.

Falconer, D.S., T. F. C. Mackay. 1996. Introduction to Quantative Genetics. 4th ed., Longman Group Limited, Malaysia.

International Year of Rice. 2004. ''Rice and Us'' fact sheet. http://www.fao.Org/ag/ irc/default.htm. Accessed in April, 2008.

Khan, A. S., M.Imran and M. Ashfaq. 2009. Estimation of genetic variability and correlation for grain yield components in rice. *American-Eurasian Journal of Agriculture and Environmental Science* 6(5):585-590.

Koutroubas, S. D., and D. A. Ntanos. 2003. Genotype differences for grain yield and nitrogen utilization in indica and japonica rice under Mediterranean conditions. *Field Crops Research*, 83:251–260.

Lee, H. J., S. H.Lee and J. H.Chung. 2004. Variation of Nitrogen Use Efficiency and its Relationships with Growth Characteristics in Korean Rice Cultivars. *Proceedings of the 4th International Crop Science Congress*. Brishane, Australia, 26 Sep-1Oct.2004.

Moll, R. H., E. J. Kamprath, and W.A. Jackson.1982. Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization. *Agronomy Journal,* 74: 562-564.

Samonte, S. O. P. B., T. W. Lioyd, C. M. James, R. M. P. Shannon, M. M. C. Anna and S.L. Joveno. 2006. Nitrogen Utilization Efficiency: Relationships with Grain Yield, Grain Protein, and Yield-Related Traits in Rice. *Agronomy Journal,* 98:168-176.

SAS Institute. 2000. The SAS system for windows, V.8.1. SAS Institute, Carry, NC, USA.

Singh U., J. K. Ladha, E.G.Castillo, G.Punzalan, A.Tirol-Padre, and M. Duqueza. 1998. Genotypic variation in nitrogen use efficiency in medium and long duration rice. *Field Crops Res*earch, 58: 35-53.

Sokat Yiech. 2006. Nitrogen uptake and yield responses of rainfed rice (*Oryza sativa* L.) varieties to fertilizer N on fluvisols of Gambella region. An Msc Thesis presented to the School of Graduate Studies of Haramaya University, Ethiopia.

Watanabe, Y.1997. Phenology and geographical distribution of genus oryza. In: "Science of the rice plant". pp.29-39. Food and Agricultural policy Research Centre, Tokyo.

Woldeyesus Sinebo, R.Gretzmacher and A.Edelbauer, 2004. Genotypic variation for nitrogen use efficiency in Ethiopian barely. *Field Crops Research*, 85: 43-60.